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# THE GEOGRAPHICAL ASPECTS OF MALARIA

SIR MALCOLM WATSON

*Meeting of the Society, 9 February 1942*

HAD you asked me fifty years ago to address you on the "Geographical aspect of malaria," I should have begun by quoting from Hirsch's monumental work (Hirsch, 1883) on 'Geographical and historical pathology,' as follows: "Covering a broad zone on both sides of the Equator the malarial diseases reach their maximum of frequency in tropical and subtropical regions. They continue to be endemic for some distance into the temperate zone, with diminishing severity and frequency towards the higher latitudes; in epidemic form they not infrequently appear yet in other regions; and, in still wider diffusion with the character of a pandemic, also beyond these indigenous latitudes." Hirsch follows this with pages describing the various countries throughout the world in which the disease occurs, and an equally extensive discussion of the conditions which influence the appearance of the disease, and of its possible cause. But the discussions lead to no final conclusion; and in the words of another writer, "As Crudeli points out, malaria exists on soils of every conceivable variety, of every age in geological time, and it is impossible to point to any mineralogical or chemical conditions which can be said to be essential." (Duncan, 1888.)

By his discovery in 1880 that malaria is caused by a living parasite, visible under the microscope, Laveran, a French Army surgeon working in Algiers, made an important addition to our knowledge. Malaria then ceased to be "a miasma," a word indicating some sort of emanation from the soil; the word was not exactly defined; and, as we have read, any sort of soil appeared capable of giving out the emanation. Then came the problem. How does this parasite circulating freely in man's blood pass from one victim to another? The genius of Sir Patrick Manson, who had carried out original work in China on another parasite circulating in the blood, provided a hypothesis, which if not wholly correct provided Sir Ronald Ross with a valuable starting-point for his researches in India. Manson also gave Ross the most generous and selfless help in other ways.

In a letter dated 5 July 1897 to Sir Charles Crosthwaite, asking him to

influence the Government of India to put Ross on special malaria research, Sir Patrick Manson wrote: "Money can build institutes, but a thousand institutes are useless if they are not manned by the right men. A good man is worth them all. I have no hesitation in saying that at the present moment Ross is the best man in India to carry on malaria investigation. To lose him therefore as I say, would be a public calamity. . . . It would be a vast pity if the chance which now presents of making a substantial addition to the pathological science should once again be lost to Englishmen. We are cutting a sorry figure alongside other nations at present. To our national shame, be it said that few, very few, of the wonderful advances in the science of the healing art which have signalized recent years, have been made by our countrymen. This is particularly apparent in the matter of tropical diseases, in which we should in virtue of our exceptional opportunities be *facile princeps*. . . . But in this matter of malaria here is a chance for an Englishman to rehabilitate our national character and to point out to the rest of the world how to deal with the most important disease in the world—malaria." (Manson-Bahr and Alcock, 1927.)

Infinite patience and the burning energy of his genius enabled Ross to overcome innumerable difficulties, and prove to the world something that neither he nor Manson quite expected: The malaria parasite was not just sucked up by the mosquito from a man suffering from the disease, or transferred mechanically. The parasite actually bred in the wall of the mosquitoes' stomach; the offspring of the original parasites when mature were injected into another man; so the disease spread. Ross discovered what the parasite looked like in all its various stages in the mosquito and where these stages were to be found; the prolonged researches also proved that not every mosquito could be infected; only some with spots on their wings, later identified by entomologists as *anopheles* mosquitoes. The mosquitoes which could not be infected are those popularly called *culex*. This was a huge step forward: indeed it constituted one of the major discoveries of medicine. For malaria kills probably more people than any single disease in the world. The stage was now set for the prevention of malaria by striking at the mosquito.

The medical profession in this connection divided into two camps: in one Ronald Ross; in the other the rest of the profession. Ross realized more fully than did his colleagues at that time the line that would have to be taken if malaria was to be prevented. In an exceedingly able report to the Government of India he wrote that while it was not possible to kill mosquitoes everywhere, it would be wise to make a beginning by ascertaining which of the mosquitoes carried malaria and which did not. Neither Ross nor anyone else working at the problem realized that before this could be successful on a large scale and especially in rural areas, many more years of research would be required with Ross's discovery as its starting-point. Nor did anyone realize at first that the very technique which Ross invented was to mislead rather than guide. For the truth is that only a few anopheles carry malaria in nature, although all anopheles can be infected in a laboratory; which made the prevention of malaria appear to be much more difficult than it eventually proved to be.

This paper must describe just what mosquitoes carry malaria in the main

geographical areas, something of the very different conditions in which they live, and the strange ways we have invented to control or destroy them. The story begins in Malaya. After seeing Malaya in 1926, Ross told the Committee of the Ross Institute that the antimalarial work done there was the greatest sanitary achievement ever accomplished in the British Empire, as it was also the first successful antimalarial work carried out in the British Empire, if not in the world. (*Ann. Rep. Ross Inst.*, 1927.)

The Malay Peninsula consists mainly of ranges of granite mountains, and coastal plains with freshwater swamps fringed by mangrove with salt and brackish water; all three are covered by great forests. Man lives there always at war with the jungle.

It was my privilege to live in the Peninsula from 1900 to 1928, to take an active part in research, and initiate the practical work for the control of malaria (Watson, 1903). In the part of the mangrove forest zone covered by every tide, no dangerous anopheles live and there is no malaria; but in the inner part, covered only by spring tides, *Anopheles umbrosus* breeds and carries malaria. If the mangrove forest be felled, another anopheles appears and this newcomer also carries malaria; to-day it is called *A. sundaicus*. Both mosquitoes disappear when the swamp is embanked and drained. In 1901 Port Swettenham was saved from closure by embanking, draining, and oiling of pools, and a very complete organization for the medical care of the people. The order to close it had actually been given by the Governor, Sir Frank Swettenham, two and a half months after it was opened, but was not carried into effect when all the facts were put before him by me.

The Coastal Plains—great swamps deeper and wider than anything in Italy—harbour *A. umbrosus* and are intensely malarial. Here drainage, and selection of sites of houses half a mile from the undrained jungle, gives 100 per cent. protection against malaria.

Attention was next turned to the hills where it was not possible to get rid of the mosquito by the simple method of drainage. The coastal hills are, when under forest, intensely malarial, because *A. umbrosus* lives in the valleys, while the inland hills are healthy under forest, because *A. umbrosus* does not live there. Both kinds of hill land are intensely malarial when the forest is felled, because yet a third mosquito appears in the picture: *A. maculatus*. It lives in sunshine, and in even the steepest mountain streams, but not where the streams are covered by jungle. This insect causes intense malaria although there may not be a swamp within miles. In Malaya yearly death rates of 300 per 1000 were not uncommon among labour forces on estates or on engineering works before effective means to control mosquitoes were devised.

Among the important discoveries in Malaya were the following:

Only three out of some thirty species of anopheles in Malaya carry malaria. We had to kill only the dangerous species to stamp out the disease; the others could be ignored. This is called "species sanitation" (Watson, 1909).

Many dangerous-looking swamps, including rice fields on the Coastal Plains, were not malarial (Watson, 1909).

In 1914 I prepared a mixture of mineral oils which rapidly killed all anopheles in even fast-running streams, but was not poisonous to men or animals. This solved a difficult problem, the intense malaria produced by

stream-breeding anopheles. By means of this mixture malaria was rapidly brought under control over large areas including rubber estates, at practically no capital cost.

In 1909 I realized that Nature controlled species of anopheles in several ways, and that by imitating her we could control malaria at little or no expense in many places (Watson, 1910; Strickland, 1915; Williamson, 1933). This was sometimes unconsciously achieved by the planters when they opened up the estates. Four years' research on estates showed that the change of species that occurred from time to time was due to changes in the conditions in the valleys. When under jungle there was one species (*A. umbrosus*) which carried malaria; when the jungle was felled and the streams freed from grass, a new species appeared (*A. maculatus*) which also carried malaria; in intermediate conditions of the stream there were half a dozen species which did not carry malaria. The knowledge of how to change species was a notable advance and is to-day the foundation of a great deal of antimalarial precautions taken in so many parts of the world. Our researches also enabled us to know where to house the people, and thus deaths were reduced to 4·9 per 1000.

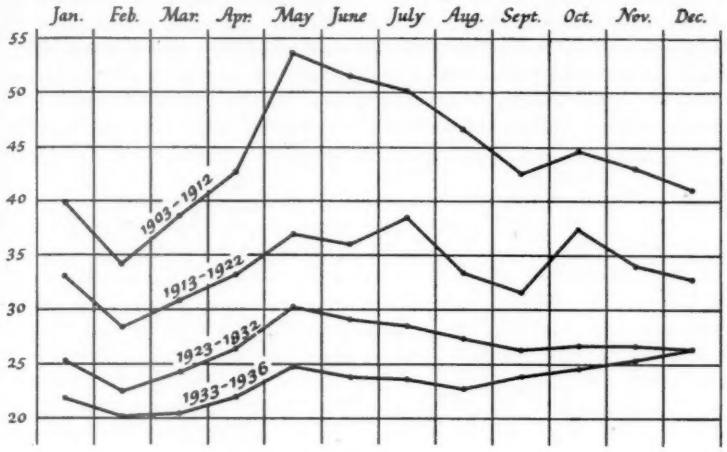
Another method devised as a result of later researches was intermittent sluicing which has a devastating effect even on mosquitoes which live in running water. Devised in Malaya, and capable of being operated by the Malay peasant, this method spread to Southern India. To-day in some of the bigger streams in the Himalaya there are batteries of sluices.

The researches and many inventions for the control of malaria in Malaya carried out by the Government and the rubber planters have thrown a flood of light on the disease in other geographical regions. So I have spoken of it in some detail. Of the work done in Malaya, Professor Swellengrebel wrote in 1935: "The principle forming the base of malaria control in Malaya ought to be the principle underlying malaria control in any country in the world. That principle of malaria control is Malaya's great gift to the world." And in 1938 he wrote: "Without species sanitation one feels helpless." (Swellengrebel, 1938.)

In 1911 I was invited to organize the control of malaria in Singapore. The disease was present not only throughout the year, but it caused a great annual wave with its peak in the month of May. Between two thousand and three thousand people died each year as a result of malaria, out of a population of two hundred and fifty thousand. To-day the population is treble that figure. Yet in 1939 the President of the Municipality could say: "Malaria has been absolutely stamped out. It would be a very unfortunate resident who contracted malaria now." It has been calculated that all health measures, of which the most important by far has been the prevention of malaria, have saved over one hundred thousand lives in Singapore in the last thirty years.

Of the value of the combination of research and practical work to the community, I may quote from an address by Mr. Eric Macfadyen (1938): "Had it not been for malaria control, British Malaya . . . could never have been realized. Its populous towns, its railways and roads which have unlocked its natural resources, the monster dredging plants, representing an outlay of millions sterling, which excavate its tin, its 300,000 acres of rubber . . . not a tithe of these developments could have been achieved had malaria remained

uncontrolled. . . . The most recent and most sensational triumph of the application of these principles has been the construction of the Singapore Naval Base. Without malaria control this great work must have cost countless lives, if indeed it could have been completed at all. To the great credit of the




*Mean monthly death-rate in Singapore from all causes*

military authorities the health problem has been handled with such success that the lay world has not known there was one, and those great works have been carried out virtually without affecting the vital statistics of Singapore."

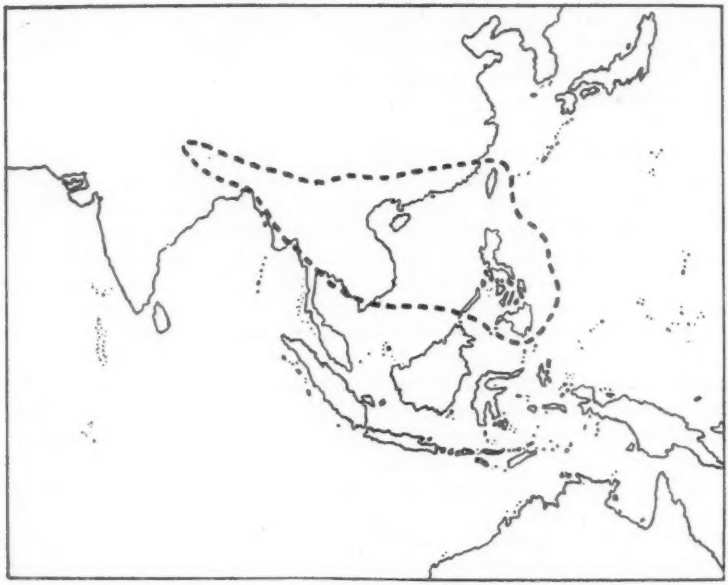
In 1913 I crossed the Straits of Malacca to Sumatra, to meet Professor Swellengrebel, who was to play a most important part in the conquest of malaria. In Sumatra, less than 100 miles from Singapore, I found to my astonishment a totally different malarial picture; for the disease was confined almost entirely to the mangrove forest zone, with *A. sundaicus* as the enemy. Hill streams, which would have been so dangerous in the Malay Peninsula, were harmless in Sumatra. In Java the picture is practically the same; although in both there are occasional outbreaks of disease away from the coast, the cause of which although interesting would take too long to explain.

Sumatra is much less populated or cultivated than Java. Indeed Java is an almost continuous sheet of wet rice, of which it would probably be true to say that over 95 per cent. is free from malaria. Sumatra and Java both differ in yet another way from Malaya. They are volcanic islands, belonging to the great volcanic chain fringing South and East Asia, including also the Celebes, the Philippines, Formosa, and Japan.

In British North Borneo researches, not yet completed and not yet published, by Dr. John McArthur, whom I am proud to claim as a pupil, indicate that the dangerous anopheles of Malaya may not be carrying the disease. *A. leucosphyrus*, a mosquito which lives at the headwaters of streams in dense

jungle, has been proved to be the important carrier in an intensely malarial area. It may be that merely clearing the undergrowth, and allowing cattle to keep the undergrowth down, will eliminate the disease, at little cost to the poor and half-starved inhabitants.

In the Philippine Islands the picture changes again. Here, as in the coastal plains of the Malay Peninsula, Java and Borneo, Siam and Burma, the rice fields are healthy. In the Philippine Islands the mangrove zone is also healthy, unlike Java and Sumatra. But along the foot-hills *A. minimus* breeds among grass in slowly-moving clear water and produces intense malaria. This mosquito is one of the great carriers of malaria, for it carries the disease not



*Area where* A. minimus *is harmful in the foothills*

merely in the Philippine Islands, but extensively in the Continent of Asia: in French Indo-China, in Siam, on the Burma Road, and not least in the great Assam valley of Northern India. To it is due the deadly Terai malaria and blackwater fever in the area along the foot-hills of the eastern half of the Himalaya in India. The brilliant researches of G. C. Ramsay, Deputy Director of the Ross Institute (1936), have proved this. His equally brilliant prevention of the disease is not sufficiently known. It is sheer white magic to wipe deadly malaria from a valley by growing a hedge of wild rhododendron or wild privet over a little stream, without interfering with the growth of the rice in the more stagnant waters of the valley. To-day there are some 5000 miles of these hedges in India.

There are in India some forty species of anopheles, only a few of which carry malaria. *A. philippinensis* causes devastating malaria in Bengal in areas

protected from river floods by embankments, but is impotent where the land is submerged each year by floods. The devastation and depopulation resulting from man's efforts to control the rivers must be seen to be believed: hundreds of thousands of acres in jungle and a million lives lost. In the Punjab *A. culicifacies* produces great epidemics. Fortunately the last bad one was in 1908.

Of the great work in improving the health of their labourers and European staffs carried out on tea, rubber, jute, and the mining industries in India a brief but interesting account will be found in the last Annual Report of Committee of Control of the India Branch of the Ross Institute (Calcutta, July 1941). Extensive work in the prevention of malaria is now being carried out by the Imperial and Provincial Governments in India, both in town and villages; I know of no country which in the last decade has done more brilliant scientific and practical work in preventing malaria than India.

Before leaving Asia for Africa we might just glance at malaria in Ceylon. There was once a great civilization in Ceylon, which was destroyed by war some eight hundred years ago. The Indians came to the island and drove the inhabitants, not for the first time, away from their culture, their ricefields, their lovely architecture, and their carving. Anopheles killed the people whenever they returned and tried to re-colonize those areas. In Ceylon there are many monuments, but the greatest is the ancient irrigation system. In every river there are a large number of dams holding up the water; that is necessary because it is not unusual for there to be less than 20 inches of rain a year over two-thirds of Ceylon. In 1934–35 an epidemic of malaria killed over eighty thousand people in a few months. The cause was a drought; absence of the flushing of the rivers allowed *A. culicifacies* to breed in profusion. It is a potent carrier of malaria in Ceylon. To-day an organization created and operated by the Government and the estates working in close cooperation would prevent such a disaster occurring again; indeed a recent drought even more severe than that of 1934–35 has failed to produce an epidemic: very encouraging, but not unexpected.

In West, Central, and East Africa there are two great carriers of malaria. One *A. gambiae* lives in sunlit pools of still water; a water current is fatal to it. The other, *A. funestus*, prefers slight shade, slightly moving water. Dense shade blots out both species, as it blots out *A. maculatus* in Malaya, and *A. minimus* in India. On the opening of the great copper mines of Northern Rhodesia, the population suffered from malaria, blackwater fever, dysentery, typhoid, and other diseases. The personal interest of Mr. Chester Beatty and his colleagues, and the exertions of the local staff, have however been so successful that the health of both whites and African employees compares favourably with that of the Panama Canal employees, and that is not a low standard.

Livingstone wrote in his missionary travels that the Lower Zambezi was the most malarial area he had visited in Africa, and that even the Portuguese suffered from the disease very severely. A few years ago the great Lower Zambezi bridge was built across the river. Thanks to the advice given by the Ross Institute through Mr. C. R. Harrison, a member of the staff of the Ross

Institute, the work was carried out with a minimum of sickness. Actually only one European out of seven went down with malaria. (*The Times*, 31 October 1934; Dixon, J. R.: "Building the Lower Zambezi Bridge." *Journal of the Royal African Society*, April 1935.)

There is some reason to hope that researches carried out by the Ross Institute on mines in West Africa will open a new chapter in that area. Unfortunately malaria is widely spread through Africa, reaching south to Durban, and north into the oases of Egypt, Libya, Algiers, and Morocco. In the equatorial belt it is intense; it rises even into the Highlands of Kenya. Nairobi itself at 6000 feet ove sea-level is not free from the disease.

Of Panama, you all know the great triumph of the U.S. Government, guided by the genius of Surgeon-General Gorgas. The French failed because they had not discovered how to control malaria or yellow fever. Success in Panama and Malaya came because Ross did not throw in his hand in the early days and because Sir Patrick Manson, so to speak, sustained Ross's hand at a critical period. In 1915 the Panama Canal represented the greatest engineering and medical triumph the world had seen. Like so many other great things it was so misunderstood, and misrepresented, that it almost became a stumbling block, and the honour of starting anti-malarial work in the U.S.A. fell to two non-medical men: Professor Herms and Mr. H. F. Gray working in California. They began in 1911. In 1916 the Rockefeller Foundation, after sending two distinguished scientists to study Malayan methods, took up the prevention of malaria in the U.S.A. and have given a great lead to that country. In passing I would mention that research and practical work carried out on the reservoirs of the Tennessee Valley Authority have developed a new method of controlling mosquitoes. By raising and lowering the level of the reservoirs a potent method of controlling anopheles has been demonstrated. It acts by stunting vegetation on the edges of the reservoirs. *A. quadrimaculatus* is the main carrier of malaria in the South East States of the U.S.A.

Although *A. maculipennis* is to be found throughout Europe from the Baltic to Cape Matapan and from Spain to the Caspian Sea, malaria is to be found mainly in the Mediterranean region. For over two thousand years malaria defied all man's efforts to reclaim and cultivate the Pontine Marshes. But within the past decade, Mussolini, by destroying the anopheles, has colonized this area; perhaps this will be his greatest, or only, abiding claim to fame. I remind you though that twenty-five years earlier we had in Malaya managed to accomplish bigger things in bigger swamps.

The Dutch quickly grasped the significance of the researches in Malaya on malaria, and when he returned to Holland from the East Indies, Professor Swellengrebel, with the aid of his colleagues, carried out some brilliant researches. They showed that there were two races (or species) of *A. maculipennis:* one of which bred in brackish water and carried malaria, the other which bred in fresh water and was harmless. This was the prelude to researches in other parts of Europe, which split *A. maculipennis* into six races (or species) some only of which carried malaria. This explained many anomalies.

A couple of hundred years ago malaria was not uncommon in England, in low-lying areas like the Fens or the Thames Estuary. Indeed, London itself was not free. But drainage and reclamation of land have wrought so many changes, that when malaria was implanted in England in 1917–18 by the soldiers returning from foreign lands, it died out within four years.

During a visit to some of Mr. Chester Beatty's mines in Serbia, I took an opportunity of visiting Salonika to see an area in which according to the official history "malaria dominated the medical and military situation." This medical disaster had come from two anopheles, *A. maculipennis* in the swamps, and *A. superpictus* in the hills, and a failure to control them. *A. superpictus* I had already seen in Albania and South Serbia. It breeds among stones in slowly moving hill streams. Its distribution is extensive. It has been mentioned in Spain and north Italy. But it is the great carrier in Sicily, Dalmatia, Yugoslavia, Albania, Macedonia, Greece, Bulgaria, Thrace, Anatolia, Cyprus, Caucasus, Transcaucasus, Cilicia, Syria, Palestine, Sinai, Upper Mesopotamia, Turkoman Republic (Transcaspia), Cossack Republic (Tashkent), Bokhara, Persia, and N.W. India. As we read the names, which I have taken from a book on the anopheles of India (Christophers, 1933), we are reminded of the victorious march of Alexander the Great against the Persian King and on to India. You will remember how, when his army refused to go farther, he sailed down the Indus and up the Persian Gulf, and how he died at Babylon. "The exploration of the waterways round about the empire was Alexander's immediate concern, the discovery of the presumed connection of the Caspian with the Northern Ocean, the opening of a maritime route from Babylon to Egypt round Arabia. The latter enterprise Alexander designed to conduct in person; under his supervision was prepared in Babylon an immense fleet, a great basin dug out to contain one thousand ships, and water communications of Babylon taken in hand." (*Encyl. Brit.* 14th ed.)

The excavation of earth and the aggregation of labourers are notorious antecedents of an outbreak of malaria; for the excavations create mosquito breeding places and the labourers supply the malaria parasites. By then it was the month of June, when malaria, as we found in the last war (Christophers, 1921) is in full blast. So we are not surprised to read: "At last all was ready; the 20th of the month Daesius (? June 5) was fixed for the king's setting forth. On the 15th and 16th Alexander caroused deep into the night at the house of the favourite Medius. On the 17th he developed fever; for a time he treated it as a momentary impediment to the expedition; on the 27th his speech was gone, and the Macedonian army was suffered to pass, man by man, through his chamber to bid him farewell. On the 28th (June 13th) Alexander died."

The fever may have been typhoid; but it all suggests malaria. Quinine was unknown to the Greeks. If it were malaria, the species that infected and killed the victor of so many fights would probably be, not *A. superpictus*, which is confined to the submontane regions of Mesopotamia, but *A. stephensi*. This is the mosquito which Ross thinks was the one he first infected with malaria in his little laboratory at Secunderabad in India.

Historians are divided about the character of Alexander, and whether this intrusion of Greek arms and philosophy into the culture and religion of the East was all for the best. That I am not competent to discuss. Nor need I

speculate on what difference it would have made had fever not cut short the life of this conqueror, and whether he would have become an equally great administrator.

But there is no difference of opinion about the debt mankind owes to Ronald Ross. I have told you something of how our nation has employed Ross's discovery. Much still remains to be done to prevent tropical diseases. There is still much to be discovered about malaria and its prevention. But in scientific research and practical prevention of malaria from 1901 to the present day, the British have given a clear lead to the world.

Though they have not done all, they have done something of what Sir Patrick Manson urged. I think we can justly claim that the British have not been unfaithful to their trust. And if we turn to an impartial witness such as Professor Swellengrebel we have his assurance that the work done in Malaya has been of great benefit to the world; without what has come to be known as "species sanitation" the fight would have been hopeless. So that Malaya, in this time of trial, can feel that she has achieved something of lasting benefit.

## DISCUSSION

Before the paper the PRESIDENT (the Rt. Hon. Sir GEORGE CLERK) said: Our lecturer this afternoon is so well known in such a number of fields that it is almost superfluous to introduce him. He is probably the greatest living authority on tropical medicine. Sir Malcolm Watson is the eminent Director of the Ross Institute of Tropical Hygiene and the inheritor of the tradition of Sir Patrick Manson and Sir Ronald Ross. Apart from that, he has applied his genius to other activities and is a great authority on rubber; in fact, he has every qualification for giving an interesting lecture. After eight years in the Malayan Medical Service, Sir Malcolm became Chief Medical Officer of the Estate Hospital Association and for twenty-eight years in all gave to Malaya the immense benefit of his scientific knowledge in the combat against malaria. This afternoon he will no doubt deal largely with that part of the world which is of poignant interest to us all at this time, but will, I understand, also review the wider geographical aspects of the fight against an enemy the ravages of which have been responsible for large-scale devastation of human life both in peace and in war. I now call upon Sir Malcolm to read his paper.

*Sir Malcolm Watson then read the paper printed above, and a discussion followed*

The PRESIDENT: Sir Malcolm Watson has indeed fulfilled my forecast: we have listened to a most brilliant and interesting paper. Mr. G. E. Cator, who was formerly British Resident of Perak, the senior State in the Malayan Federation, and who is now head of the Malay Information Agency in London, is present with us, and would perhaps from his personal experience speak of the work done in Malaya.

Mr. G. E. CATOR: I certainly can from my own experience speak of the remarkable work that has been done in Malaya in the prevention and control of malaria, in which work Sir Malcolm Watson has played so brilliant and prominent a part. I went out to Malaya in 1907 and left there three years ago. When I went out it was regarded as the ordinary course of nature to have at least one turn of malaria a year, and the dosage of quinine always had to be taken regularly. We were all more or less adversely affected, either by malaria or the con-

sequences of it. But during the fifteen years before I left Malaya I should have been as surprised to get a bout of malaria as I should have been to be bitten in the leg by a sheep.

Singapore stands partly on built-up mangrove swamp. In the Straits Settlements of Penang, Malacca, and Singapore, with a population of nearly two million in 1938, the last year for which I have figures, less than one thousand deaths occurred as a result of malaria. Sir Malcolm has told us that the death-rate on large labour estates used to be something like three hundred out of one thousand. Malaya was a very much-governed country, with no less than twelve separate and distinct governments in an area about the same size as England. All paid the greatest possible attention to anti-malarial work; it was a regular feature of all government organizations. Everywhere there were two different Boards: the Malaria Board, which was charged with the control and prevention of malaria, that is to say, the extermination of malaria-carrying mosquitoes, either by drainage or oiling or by other methods; and there was the Mosquito Board whose job was to acquire knowledge of the habits of every kind of mosquito. There was no district too small to have its anti-malarial and anti-mosquito boards, and not a single district in which a great deal of money was not spent, wisely and well, on investigating the problem and combatting the scourge. The results are known to you. It is particularly sad to feel that all this great preventive work has for the moment been swept away and will have to be re-started when the Japanese have been turned out. The only satisfaction is that in the Ross Institute we have the records of what has been done, and that can be done again.

The PRESIDENT: We are also fortunate this afternoon in the presence of another man to whom humanity owes an unpayable debt for help in the fight against this scourge. Sir Malcolm told you a little of what our guest had done. Without his help I do not suppose the fight against malaria would have been so far advanced or so successful as it has actually been. Will Mr. Chester Beatty be good enough to speak?

Mr. CHESTER BEATTY: Sir Malcolm and others are exaggerating any part I have played in this fight. I think Sir Malcolm of all men deserves the credit, and that he ranks with Manson and Ross. They worked out, to a certain extent, the theoretical points, and began the application of methods to fight the scourge. But Sir Malcolm has introduced those methods into many different parts of the world and developed the technique which is so essential to success. You will have noticed that there are many varieties of mosquitoes, and that they live under such different conditions that the problems are most complicated. Each one has to be taken by itself and solved individually.

Unfortunately one has not much choice in selecting where a mine is to be located, otherwise I would have selected a location for the diamond and copper mines in Cornwall. We happened to select particularly bad places, and it seemed to me that health and the solving of these health problems were just as important in their way as metallurgical questions. I was going through a fine power plant in Yugoslavia and remarked to the manager: "You realize, of course, how many power plants you have in this particular plant?" He said: "No, we have this central plant." I said: "No, you have 2000 power plants, and you are using the worst kind of fuel to run those plants, for you have the vilest food on this property that I have ever tasted. If you cannot reorganize the food you can send in your resignation." From that point of view we approached the problem, and Sir Malcolm Watson started the organization in the diamond fields on the Gold Coast and in the copper mines in Africa and Yugoslavia. As a result the health rate in the African copper mines is better

than it is in Kensington; if we could all go out there this afternoon I could guarantee superior health conditions, and climatic conditions far superior.

In the diamond fields on the Gold Coast and Sierra Leone I believe not a single life has been lost from malaria among the white population during nearly ten years. The mines in the Balkans were investigated and put on a very high standard, and I think that instead of following the war with a period of reconstruction in Europe and the Balkans it would be wise first to improve the health of the population by tackling the malarial conditions. There is no greater gift or aid we could give to the Balkans than to pass on, through Sir Malcolm Watson, his experience and the benefits of the great achievements he has accomplished elsewhere in the world.

Admiral Sir WILLIAM GOODENOUGH: I have been impressed by the superlative interest of what we have heard this afternoon. No aspect of the problem has been left untouched. There is no body which owes more to the research into the prevention of malaria than the British Navy. When I first went to the West Coast of Africa some fifty years ago it was almost impossible to find a man who was not either down with, recovering from, or expecting to go down with, malaria. Years afterwards, when I went there as Commander-in-Chief, what did we find on the West Coast? Healthy districts in which one could live with security and safety.

The PRESIDENT: I only wish Sir Malcolm had been working many years earlier, because then I should not have suffered from contact with a criminal whose name I learned for the first time this afternoon. Perhaps I am now proud to think I was the victim of *A. funestus*, which very nearly killed me. Thanks to Sir Patrick Manson I eventually recovered and am therefore able to express to-day, on your behalf, our grateful thanks to Sir Malcolm Watson for a wonderfully interesting lecture. At the same time I add our thanks to those who followed him and contributed from their experience.

Sir MALCOLM WATSON: May I add a word or two I wrongfully omitted? I did not mention the wonderful work done by the rubber planters. I have seen it stated that people in Malaya lived a luxurious and riotous life. Believe me, it was the best of our race who built up Malaya in the old days when everyone was frequently down with malaria. The Europeans used to be knocked senseless by it, but when they were able they struggled up and out only to find that labour forces had disappeared from their plantations. That sort of thing went on repeatedly, but those men struggled on; with the help of the Government and their own exertions they ultimately won; and if we have done well out of Malaya, we deserve it.

# A SURVEY OF ANCIENT SITES ALONG THE "LOST" SARASVATI RIVER

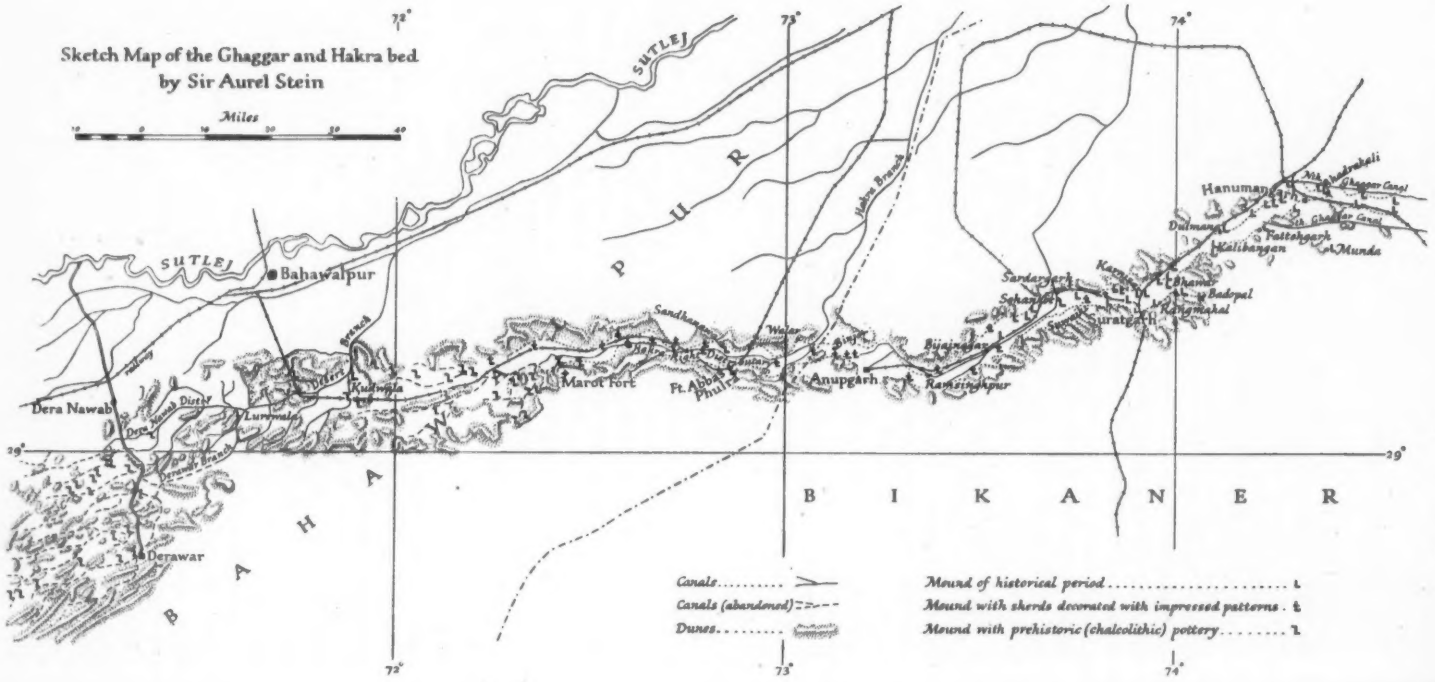
SIR AUREL STEIN, K.C.I.E., F.B.A.

ON my return to India from the explorations of 1938–39 along the Roman frontier defences of 'Iraq and Transjordan, a survey of any remains of ancient occupation along the dry river-bed of the Ghaggar or Hakra, which passes from the easternmost Panjab through the States of Bikaner and Bahawalpur down to Sind, seemed attractive. Traditional Indian belief recognizes in this well-marked bed the course of the sacred Sarasvati, once carrying its abundant waters down to the ocean and since antiquity "lost" in desert sands. There is no history of this great physical change. My Central Asian expeditions had shown me that where rivers have long ago ceased to carry their life-giving water, the chronology of important physical changes, as marked by remains of human occupation since prehistoric times, can be traced more easily than is possible elsewhere.

The climate of the Indian Desert, dry enough nowadays, is far removed from that extreme aridity of that true desert which in Chinese Turkistan has allowed relics of ancient life to survive in such remarkable preservation. But observation of topographical features along extensive stretches of that dry river bed, locally still well known, and the study of old sites on its banks, might throw some light on the period when water permitted there continuous agriculture and thus, perhaps, on the chronology of the process which led to water ceasing to flow in the bed. Any such indications would bear on the much discussed question of desiccation in Asia. Indirectly they might also be helpful to the student of early Indian history, still so much obscured by the want of reliable records and the inadequacy of archaeological evidence.

A tour in Kashmir in the autumn of 1940 did not allow me to start field work in Bikaner until the middle of December. The Political Department of the Indian Government helped to secure very generous arrangements for the survey from Maharaja Ganga Singhji, that remarkable ruler of the Bikaner State. Field work promptly started enabled me within less than six weeks to examine the large series of ancient mounds along the Ghaggar within Bikaner territory over a total distance of some 110 miles and to test two interesting sites by trial excavation. Proceeding thence through Jodhpur and Jaisalmer in Western Rajputana, the State of Bahawalpur in the Panjab was reached at its southern extremity. Thanks to the support kindly accorded by the Hon. C. P. Skrine, O.B.E., Resident for the Panjab States, very effective help was received here also from the State authorities, in particular from Mr. E. Anderson, C.I.E., Minister of Public Works and Irrigation, and Mr. H. Trevelyan, I.C.S., Deputy Commissioner. Within Bahawalpur territory still more numerous ancient sites, mainly prehistoric, were traced and surveyed for some 150 miles along the dry bed of the Hakra, as the continuation of the Ghaggar is known here, from the Bikaner border down to its deltaic portion below Derawar. Heat stopped field work by the middle of March.

Throughout the tour I was assisted on the topographical side by Surveyor Muhammad Ayub Khan, late of the Survey of India, my old travel com-


Sketch Map of the Ghaggar and Hakra bed
by Sir Aurel Stein
Miles
SUTLEJ
Bahawalpur
Dera Nawab
Derawar
Lurewala
Kudwala
Marot Fort
Ft. Abbas
Phulra
Anupgarh
Ramsinghpur
Sandhana
Hakra
Ghaggar
Jabra Branch
Sirsa
Sardargarh
Sahajusar
Surat
Bhadra
Badnpal
Kalibangan
Pattangarh
Munda
Hanuman
Dulmana
Sib Ghaggar Canal
Bhagsar Canal
Nohar
Bhatner
Canals
Canals (abandoned)
Dunes
Mound of historical period
Mound with sherds decorated with impressed patterns
Mound with prehistoric (chalcolithic) pottery
72°
73°
74°
29°
B I K A N E R

panion on successive journeys in Iran. After leaving Bikaner willing help was afforded also on the archaeological side by Mr. Krishna Deva, a young scholar attached to the Archaeological Survey of India. Rao Bahadur K. N. Dikshit, its present Director-General, had before shown a very helpful interest in the object of the tour by a spontaneous offer of a grant of the Department towards its expenses. A detailed report has been prepared and will be published among the *Memoirs of the Archaeological Survey of India.*

The Ghaggar and its several affluents rise as torrent beds in the Siwaliks that fringe the outermost of the Himalayan ranges. After passing down to the Ambala district, they soon cease to be perennial streams. The easternmost, still known as the Sarsuti (the Hindi derivative of Sarasvati), passes the sacred sites of Kurukshetra near Thanesar, a place of Hindu pilgrimage; it is for the most part of the year only a modest rivulet. Farther down, some 50 miles below the town of Ambala, when the Ghaggar has gathered all its tributaries and has entered Patiala territory, it flows in its wide sandy bed for only some months. Where it approaches the Bikaner border, after passing through Patiala territory and the western portion of the Hissar district, the reservoir of Otu was constructed some forty years ago, with a weir to hold up flood water for feeding two small canals in Bikaner territory. But these suffice to irrigate only very narrow belts of land on either side of the Ghaggar for some 30 miles westwards, the available water each year varying greatly with the monsoon rainfall. The area thus irrigated down to near the small town of Hanumangarh forms even in good years but a small portion of the land shown by revenue records as cultivable within the *Tahsil*; what little water is left in the Ghaggar itself suffices only for a still smaller portion of ground in its bed. Its flow has stopped in most years above Hanumangarh; rarely is it known to have extended so far as 16 miles below.

The sketch-map based on the latest survey shows how great is the contrast between the very scanty volume of water brought down by the Ghaggar and the width of its dry bed within Bikaner territory; over more than 100 miles it is nowhere less than 2 miles and in places 4 miles or more. This bed is lined on both sides by dunes varying in height but gathered into continuous bands or ridges. Seen from a distance these might suggest river banks, but they show no marks of erosion.

Their interpretation was taught me in the Taklamakan and Lop deserts of the Tarim basin, where the river beds, whether still receiving some water or dead for ages, are always flanked by continuous ridges of high dunes. The wind-borne sand from adjacent deserts is stopped by the vegetation growing in riverine belts once reached by seasonal inundation. The gradually rising accumulation of drift-sand, usually protected by some growth of scrub, has prevented the onward move of fresh dunes and thus preserved the dry beds from being smothered. Exactly the same was often seen in the Tarim basin along the edges of cultivated ground, whether still tilled or abandoned for ages.

Within the riverine belt clearly marked by these high marginal ridges of sand the Ghaggar once carried its shifting course; but there is no reason to assume that it ever filled it completely. The bed shows a firm loamy soil, easily distinguished from the light sand on either side. Whenever it receives

adequate moisture it proves very fertile. The striking appearance of the marginal ridges, helped by this difference of the soil, accounts for the popular belief that the bed of the Ghaggar was once the course of a mighty river filling it completely. Both on the Ghaggar and its continuation the Hakra, I found this notion reflected in popular legends.

The scanty and very irregular rainfall lower down the Ghaggar is determined almost solely by the monsoon and subject to extreme variations. At the Bikaner Observatory for the thirty-five years 1879–1913 the annual average was 10·93 inches, yet that period included years as low as 5·80, 3·40, and 1·14 inches. Where irrigation by canals is not available the uncertainty of crops makes the rural population dependent largely upon a pastoral livelihood, and even this is precarious in years when wells and tanks dry up.

The special interest of the Ghaggar or Hakra arises from the fact that traditional belief recognizes in that dry bed the terminal course of the Sarasvati river mentioned in many hymns of the "Rigveda," the oldest surviving record in any Indo-European language. In later Vedic texts it certainly bears the character of a sacred river which attaches to the present Sarasvati in the classical Sanskrit literature and religious tradition of India. In at least three passages of the Rigveda mentioning the Sarasvati, a river corresponding to the present Sarsuti and Ghaggar is meant. For this we have conclusive evidence in the famous hymn, the "Praise of the rivers" (*Nadistuti*) which, with a precision unfortunately quite exceptional in Vedic texts, enumerates the *Sarasvati* correctly between the *Yamuna* (Jumna) in the east and the *Sutudri* or Sutlej in the west.[1] In a much larger number of passages of the Rigveda the Sarasvati is referred to as "the foremost of rivers," as flowing into the ocean, and otherwise extolled for its greatness in a way which seems difficult to reconcile with the Sarsuti and Ghaggar of the present day.[2] This difficulty induced Professor R. von Roth to recognize the Sindhu or Indus in the great river of these passages, and in this he has been followed by other scholars. The survey briefly described below may, perhaps, help to remove some of the doubts raised by that apparent discrepancy.

Taking first the Ghaggar bed above Hanumangarh, one notes that the number of mounds marking ancient sites long abandoned is here distinctly smaller than farther down the old river bed. Such mounds, known locally by the terms *ther* or *theri* (in the case of the smaller ones) are bare of all vegetation and covered with pieces of broken pottery; these mark prolonged occupation before the sites were abandoned. The long erosion by wind and rain has gradually brought to the surface sherds dropped at different times and embedded in varying levels. This thick cover of sherds makes these ancient mounds easily recognizable from a distance and well known to the people. It is not found where occupation has continued down to recent times or has been resumed later.

[1] For the list of rivers between the Ganges and the Indus, given in due geographical order, see my paper "On some river names in the Rigveda," *Journal of the Royal Asiatic Society*, 1917, 91–99.

[2] A careful synopsis of all Vedic passages which mention the Sarasvati and of the different views held by Indologists on their interpretation, is presented by Professors Macdonell and Keith, 'Vedic index of names and subjects,' ii. pp. 434 ff.

Such mounds are more numerous lower down the Ghaggar than near and above Hanumangarh, and also, I have reason to believe, farther up within the Hissar district; this is readily explained. Within the Hanumangarh Tahsil, cultivation is still facilitated by such irrigation as the two branches of the Ghaggar Canal and the periodical descent of flood water in the *Nali* within the Ghaggar afford. Hence there are here also more settlements still in being. Small as they are they are apt to cover up the traces of former occupation. The imposing ruined fort at Bhatner close to Hanumangarh, which figures in recorded history during medieval times and later, stands on a big mound, rising to some 100 feet, and is very early, probably prehistoric. But owing to later debris and refuse deposited on the slopes below the walls of the fort during continuous occupation, no specimens of those characteristic types of ceramic ware, common on all thers, were here on the surface.

At almost all the mounds which the map marks within the Hanumangarh Tahsil, fragments of that painted or relief-decorated pottery could be found which can be definitely assigned to early historical times down to the Kushan period or the first two centuries of our era. Some 4 miles to the east of Hanumangarh lies the mound of Bhadrakali, called after a Hindu shrine standing at its eastern end and attesting here as usual "continuity of local worship." The mound measures fully 300 yards long and rises to some 43 feet above the surrounding ground which, owing to occasional flooding from the Nali and thanks to intelligent protection, still bears thin tree growth. Here painted sherds of the early historical type could be picked up in plenty on the surface. At Fattehgarh to the south-east the mound which, though extensively dug into for manuring earth and for saltpetre, still rises on its crest to 47 feet, displays the same early painted ware both on its surface and deep down in layers exposed by these diggings. The great difference in levels affords proof of the prolonged period during which that ceramic type prevailed.

Clear chronological evidence regarding the time down to which this type remained in use was afforded by a short but profitable trial excavation at the small village of Munda, not on the Ghaggar but about 10 miles to the south-east of Hanumangarh in dune-covered ground known throughout Bikaner as *Dora*. Its people, mainly pastoral, carry on some precarious cultivation with the help of tanks and deep wells. A sandy spur, rising some 50 feet near the hamlet, carries on its top a small modern shrine of Hanuman, the monkey god. Remains of terracotta sculpture from a badly destroyed Hindu temple were found close by almost on the surface. Their style showing Graeco-Bhuddhist influence pointed to the Kushan period, and this was confirmed by the discovery of a *cache* of Kushan copper coins comprising several issues, lower down on the slope. A trial trench cut down from the level of the ruined shrine disclosed painted pottery of the above type for some 10 feet lower. The same date was subsequently derived from the Rangmahal site.

The definite dating of this painted ware with well-executed geometrical and floral designs has its special interest. It marks the period of occupation also for the sites surveyed above and below Suratgarh, the small town lower down on the Ghaggar bed. It is plentiful on all the numerous and mostly large thers traced along and within this stretch of the Ghaggar for more

than 30 miles. The large number of these ancient sites contrasts strikingly with the very few small villages still on the same ground. Apart from Suratgarh, which owes its size to being the trade and administrative centre for the whole district, the dwellers in these hamlets live far more on their flocks, cattle, and camels than on their small plots of precarious cultivation wholly dependent on the spasmodic rainfall. How limited the number of people living in these villages is can be realized from the statistical record of 1901, the latest accessible to me in the *Bikaner Gazetteer*. For the Suratgarh Tahsil, comprising an extensive desert area of Dora, the record of 1901 showed a total of eighteen thousand souls (including the town of Suratgarh) living in one hundred and twenty-six villages.

How much larger the agricultural population must have been in early historical times is shown by the number and size of the mounds proved more or less contemporary. Irrigation from the summer floods in the Ghaggar bed permitted agriculture to an extent quite impossible at present.

Among the twenty-four main sites which the sketch-map shows between Dulmana and Sohankot, Rangmahal is of particular interest. It is about 3 miles to the east of Suratgarh, where the Ghaggar bed makes a marked bend at the foot of a projecting high sandy spur on the south. The name Rangmahal, "the notable mansion," suggests the importance of the site. Several mounds along the foot of the spur and some structures on the northern slope of the latter have been repeatedly quarried for their burnt bricks, first about the year 1800 to build the fort of Suratgarh, and much later for metalling the permanent way of the railway. From numerous terracotta sculptures of the late Kushan period which have found their way into the walls of the fort and thence partly into the Bikaner Museum, it is certain that these structures comprised at least one Hindu temple. A small modern shrine on the slope of the sand spur indicates here also the continuity of local worship. The spur rising to fully 150 feet is connected with a chain of high sand ridges stretching east and west of Suratgarh. This shows how far back reaches the accumulation of dunes which accompany the bed of the Ghaggar and are now taken for its "banks."

The principal mound of Rangmahal is about 300 yards in diameter and rises to 35 feet, thickly covered with sherds. The plentiful painted fragments among them can be definitely assigned to early historical times ending with the Kushan period, and the numerous terracotta figurines on the surface and down to 15 feet below, all clearly show the influence of the Graeco-Buddhist art of Gandhara. The absence of glazed pottery here and along this portion of the Ghaggar points to abandonment long before Iranian influence was established through Muhammadan domination in the north-west of India. The large ancient tank lined with massive walls of burnt bricks near the principal mound suggests occasional failure of water supply even when the site was still occupied.

Among other sites along the Suratgarh stretch of the Ghaggar a few only need be noted. The Thers of Karnisar and Bhawar, both within 4 miles of Rangmahal, have a circumference of fully half a mile, the second one rising to some 40 feet. At both painted sherds of the same type as at Rangmahal, including also animal figures, could be picked up on the surface in abundance,

at Karnisar also a few Kushan coins. From the mound at Badopal, 7 miles east of Rangmahal, and fully a quarter mile long, terracotta relievos from a Hindu temple, somewhat later than the one at Rangmahal, had been previously removed to Bikaner. Two large mounds close together some 14 miles to the north-east of Rangmahal and not far from the abandoned hamlet of Kalibangan offer interest as marking an extensive site used mainly for burning bricks and for pottery. They measure together some 600 yards in length and 450 yards across, with a maximum height of 30 feet. They are composed almost entirely of kiln remains. The painted sherds found among them leave no doubt about the kilns having been worked down to the Kushan period, and the size of the area shows the demand for their produce. A large tank-like depression near the mounds marks the place where the clay had been dug and water kept.

To the west of Suratgarh down the Ghaggar the number of mounds diminishes. The ther close to the small village of Sardargarh, with a diameter of nearly 500 yards, still shows plenty of painted pottery, but this comes to an end at the mound of Sohankot, about 3 miles farther to the south-west and now much reduced by recent digging for manuring earth. The Ganganagar canal brought in recent years from a great weir constructed on the Sutlej below Firozpore has brought new settled life to the dry river bed.

South-east of Sardargarh at the two smaller sites of Suwaiki and Bhaironpurs, close together, flat patches of ground show, among debris of plain pottery, decorated sherds of a quite distinct type, unpainted and bearing coarsely impressed geometrical patterns with hachured or herring-bone designs. This type of ware, found also at certain sites lower down, unmistakably marks a different period of occupation.

The Anupgarh Tahsil begins where the new canal enters the bed; it takes its name from the only old village in it. Within this area no painted potsherds of the Rangmahal type could be found. The very few mounds of any height had indeterminate plain ware and scarce fragments decorated with simple black bands or coarsely impressed patterns. But a single small worked flint blade, the first prehistoric relic picked up along the Ghaggar, contrasted with the abundance of stone implements within Bahawalpur territory.

From the border of the Bikaner and Bahawalpur States the dry riverine belt is known as the Hakra. It becomes wider and near Walar, above the new colony of Fort Abbas, a distinct gap in the northern sand ridges brings the Hakra Branch of the great new canal system. This canal has brought water and cultivation along a portion of the Hakra bed which had long known no settled agricultural life, and also into the Cholistan, the wide desert belt north of the Hakra.[1]

Careful study of the large-scale levelling charts prepared by the Survey of India for the Sutlej Project when this important canal scheme was being planned by the Panjab Irrigation Department, has shown me that the Hakra Branch canal passes for some 104 miles across levels between the sand ridges

[1] It is of interest to find the term *chol* or *chöl*, meaning "desert," which is of Turki origin and common in Eastern Turkistan, localized as it were with the added Persian ending in this part of the Panjab. It was brought there, no doubt, by invaders from south-eastern Iran, the latest of whom are the Baluch, found also in Bahawalpur.

of the Cholistan which unmistakably represent an ancient winding bed of the Sutlej, that once joined the Hakra between Walar and Binjor.

The junction of the Hakra with a branch of the Sutlej must have meant a great increase in the volume of water, and accounts for the Hakra bed widening below the junction about Walar.

Archaeological facts prove cultivation, and with it settled occupation, to have been abandoned much earlier on the Hakra than on the Ghaggar. Prehistoric mounds with pottery of the chalcolithic period appear first near Fort Abbas. Thence they were traced right down the Hakra as far as my survey extended west of Derawar.

A trial excavation at Sandhanawala Ther, 3 miles to the north-west of Fort Abbas and rising to some 28 feet above the now irrigated ground at its foot, showed that remains of chalcolithic times are contained in its layers right through to the virgin soil of river silt. Here, as at other high mounds farther down, painted pottery closely resembled that of numerous chalcolithic sites explored by me in British Baluchistan and Makran,[1] and also that of the now well-known great Indus Valley sites. Fabric and designs clearly distinguish this ceramic ware from the painted pottery of early historical times found at the mounds up the Ghaggar. Some sherds with incised characters which appear on many inscribed seals from Mohenjodaro and Harappa, chief sites of the Indus Valley culture, assign the Sandhanawala deposits to early in the third millennium B.C. Worked flints are associated with the chalcolithic pottery at this and the very numerous prehistoric mounds traced farther down the Hakra, and there is close similarity in the shapes of vessels, terracotta, and shell ornaments.

For some 30 miles up to the Sandhanawala mound these sites of prehistoric occupation are interspersed with other mounds generally smaller and much lower, showing no painted sherds or worked flints, but with the same coarse ceramic ware with impressed or incised patterns, seen at some sites below Suratgarh. Now from varied evidence we may conclude that this unpainted type is later than the chalcolithic painted, but preceded the other painted type at most of the sites along the Ghaggar. I suggest that prehistoric occupation along the Hakra had stopped lower down after the branch of the Sutlej had ceased to join it, but for a time the floods of the Ghaggar may still have sufficed for cultivation in a stretch of the bed, until later settled agriculture became restricted to the Ghaggar higher up in Bikaner territory.

This must for the present remain conjectural. But it may be considered as certain that the riverine belt along the Hakra from about the assumed confluence with an old bed of the Sutlej down to Derawar knew no settled agricultural life during historical times. What small settlements existed near the Hakra before the modern canal system reached it were those of a very scanty pastoral population, maintaining itself partly by the supply of camel transport for caravan traffic following an old route much used until the advent of railways. It led from Multan and Sind towards Delhi and other main centres of northern India. A series of forts more or less aligned on the Hakra

[1] See descriptions and illustrations in my contributions to *Memoirs of the Archaeological Survey of India*. No. 37, "An Archaeological Tour in Waziristan and Northern Baluchistan," and No. 43, "An Archaeological Tour in Gedrosia."

from Derawar to Phulra served as stages on this route and for protection against raids.

Very numerous mounds are found all the way down from where the Hakra Branch enters the dry riverine belt to where the Desert Branch canal fed by the same main head on the Sutlej joins in from the north-west after crossing the Cholistan. On the sketch-map the prehistoric mounds with chalcolithic painted pottery are distinguished from those with plain ware and sherds decorated with coarse patterns. While these sites of presumably later occupation were traced only within the main Hakra bed, the prehistoric ones are both there and on branching side beds, now known as Dahars.

Into these have been conducted smaller channels, designated Minors by the Irrigation Department. But it was sad to note that all these as well as the terminal portion of the Hakra Distributary have had to be abandoned below Marot since their construction. The water in the Sutlej at the canal head had against expectation proved inadequate to irrigate so far down, and the sand was reclaiming ground recently tilled. The same applies also to most of the Minors which the Derawar Distributary of the Desert Branch was intended to feed.

It is probable that the Desert Branch canal follows an ancient bed of the Sutlej, which might explain two notable facts. From Kudwala onwards all the mounds to the west and south-west display both painted pottery of chalcolithic type and unpainted pottery with relievo patterns of a very characteristic kind. And these sites, prehistoric, as proved by abundant finds of worked stone implements, become particularly numerous to the north of Derawar.

Some eighteen mounds were examined over an area close on 100 square miles. This is to a great extent overrun by dunes between which long stretches of flat ground are recognizable as branching dry river beds. The whole looks deltaic. Floods descending the Hakra could not have made such a network of terminal channels. But if a branch of the Sutlej also flooded this flat ground beyond the great fringing sand ridges on the south, and thus made extensive irrigation here possible, its close occupation by prehistoric settlements is intelligible.

The great height and size of several thers indicate prolonged settlement. Thus the conspicuous mound of Kudwala rises to more than 50 feet and has a length of close on three-quarters of a mile. The mound of Lurewala, some 9 miles farther west, though somewhat lower, is larger. Only excavation could estimate the time of accumulation, or the chronological relation between them and the prehistoric settlements farther up the Hakra. But at only one site in this area has occupation continued beyond prehistoric times.

That is the great mound close to the much-restored fort of Derawar which from medieval down to modern times was a stronghold of those who ruled the desert now divided between Bahawalpur, Bikaner, and Jaisalmer. It was one of the border posts of the old caravan route along the Hakra. The ground was as barren then as it is now since the new canal failed.

The mound rises to more than 50 feet and measures about 1300 by 900 yards at its foot. Debris on the surface includes sherds from later times, but large cuttings made recently on the slopes under official orders in search of

"treasure" have disclosed prehistoric pottery in successive layers. We were fortunate to discover an ancient burial ground at the foot of the mound with remains, almost on the surface, which cannot be later than chalcolithic.

With this my work along the Hakra closed for the present. It would be hazardous to correlate the archaeologically attested changes of conditions along the Ghaggar–Hakra bed with the reference found in Vedic texts to the Sarasvati river; but the evidence shows that down to historical times the Ghaggar carried water for irrigation under existing climatic conditions much farther than it does now. This makes it intelligible how the Sarasvati has come in hymns of the Rigveda to be praised as a great river. The interval between the time when that notion found expression in Vedic poetry and the time when the Ghaggar was joined by a branch of the Sutlej, may not have been so great as to efface traditional knowledge of the entire river having once been large enough to make its way as far as the Panjnad and the Indus. The width of the Ghaggar–Hakra bed is so great that even now local folklore believe in its having once been completely filled by a large river.

A great change has affected the Sarasvati river or Ghaggar since reference to it was made in Vedic texts, which can scarcely have been composed before the second millennium B.C. at the earliest. This change may be attributed to two distinct physical causes. As regards the upper portion of the ancient bed archaeological evidence attests a drying up during historical times which is likely to have been at work in prehistoric. It might have been hastened by diversion of flood water for irrigation brought about by more settled conditions and the resulting pressure of population.[1] Lower down on the Hakra the main change was due to the Sutlej having in late prehistoric times abandoned the bed which before had joined the Ghaggar: the result of a law affecting all rivers whose course lies over alluvial plains. We have clear evidence that the drying up was gradual, at least in the historical period.

[1] In my paper "Desiccation in Asia, a geographical problem in the light of history" (*Hungarian Quarterly*, Spring Number, 1939), I have indicated instances, modern or comparatively recent, where physical changes which might suggest desiccation can be proved to have directly or indirectly resulted from human activity as attested by history.

# THE EARLY HISTORY OF WATER-SUPPLY

C. E. N. BROMEHEAD

*Continuation of a paper from the March Journal*

*Aqueducts*

THE idea of bringing a supply of water from a distant source to the required spot by some sort of artificial channel may have arisen in two ways. In low-lying ground near a river it is easy to extend the well-watered and therefore fertile area by irrigation channels; this plan would readily suggest the cutting of a similar channel, leaving the natural watercourse higher up, following a gentler gradient and so bringing a supply to a site well above flood level and suitable for a permanent settlement. But it is a far cry to anything resembling the famous aqueducts of Imperial Rome, which went round spurs of high ground or tunnelled through them, crossed valleys on arches and so brought water completely out of its natural valley. Another line of ancestry, besides the irrigational, can however be traced. Hill-top sites are naturally defensible and equally naturally waterless; but on most hill slopes springs are given out which can in peace time supply the inhabitants on the top. To obtain supplies in war-time an underground passage from within the fortifications to the known source outside is a practicable proposition. An instructive case which has been excavated and described is that of Megiddo, dating from about the time of Solomon (say 950 B.C.). A spring of good water existed in a cave at the foot of the Tel. A site for a shaft was selected and the direction of a tunnel from its foot to the cave fixed. The shaft was rectangular and placed diagonally to the tunnel line; by this arrangement the longest possible sighting line could be projected to the bottom. The direction of the tunnel was highly accurate, more so than that of work begun simultaneously from the cave end, which was joined to it by an oblique cut. At first the tunnel was merely a safe and secret way for reaching the spring; water was carried along it by hand and then hauled up the shaft. Later a slightly deeper channel was cut in the floor and the water flowed to the foot of the shaft.

Similar work is known at Lachish, Gezer, and Jerusalem. At Mycenae the spring called Perseia outside the walls feeds an underground reservoir approached from inside the walls by a secret underground passage; the work is assigned to the thirteenth century. Similar tunnels could obviously be cut right through a hill from one valley with abundant supplies to another less favoured or needing more to satisfy its inhabitants. A remarkable instance was described long ago by Thompson in 'The land and the book.' Near the southern end of Lebanon is a copious spring which is the source of the river Zahrany. "The ancient Sidonians coveted this ice-cold water, and did actually lead it to their city, along a line of canal which might well confound the boldest engineer. A channel was hewn in the rock, into which the new-born river was turned, and thence carried down the gorge southward until it could double the promontory of Jerju'a, after which it meandered as it could northward for eight miles, spanning deep ravines over high arches, and descending into Wady Kefrah below Jeba'ah. Beyond this the aqueduct was

led along frightful cliffs, where goats can scarcely keep their feet, for more than a mile, and thence it followed the ridge of Kefr Milky, past the village, into the Wady of the Sanik, where it was joined by another aqueduct from Neb'a or Râhib, the source of that river. The two canals were taken thence down the river, but separately, one about fifteen feet above the other. The system of arches by which these were carried across the ravines and rivers is still almost perfect, and the cliffs to which they cling are absolutely perpendicular for miles together. As there are no traces of arches by which the water was led across the low plain up to the city, it has been conjectured that the Sidonian engineers were acquainted at that early age with the principle in hydrostatics that water will rise to the level of its source. People also tell me that fragments of earthen pipes, incased in lead, have been dug up in the gardens in the probable line of these canals. These may have served to conduct the water to the city." The total length is about 15 miles.

More exactly dateable is the aqueduct of Nineveh, whose maker, Sennacherib, recorded on the masonry "To make the orchards luxuriant I cut and directed a canal with iron pickaxes from the borders of Kisiri to the plain about Nineveh through mountain and lowland." The aqueduct brought an additional supply from springs in the mountains into the river Khosr which enters the Tigris from the east at Nineveh; part of it, where it crosses a valley, is on masonry arches for some 300 yards, up to 30 feet high in the middle (Jacobson, T. and S. Lloyd, 'Sennacherib's aqueduct,' London, 1935). About the same time Hezekiah brought the water of Siloam into Jerusalem: a distance of 1100 feet had to be tunnelled, but parties working from the two ends nearly passed each other, and the length of tunnel constructed is about 1760 feet with a fall of 1 foot.

A conduit about 7 miles long brought water from the upper Thymbrius to Troy about 700 B.C. It is crossed at one point by a Roman aqueduct. The most famous Greek aqueduct is that of Samos, designed and carried out by Eupalinus before 600 B.C. It includes a tunnel 1400 yards long, which was cut 8 feet square in section from both ends; the meet was very nearly accurate in plan, 4 feet out in elevation. Within this the actual water-channel was cut about 3 feet square. There were several similar aqueducts at Athens, that from Mount Pentelicus being noteworthy for the number of air shafts, of which about sixty can be recognized; they were spaced at intervals of about 50 yards. Many other Greek aqueducts are known, that at Pergamon being important on account of its great siphon mentioned below.

The Romans developed this system on a large scale; the remains of raised aqueducts are familiar features in Southern France, Spain, Northern Africa, and, of course, in Rome itself. In A.D. 97 Frontinus, who had held an official position in Britain at Caerleon in A.D. 78, was appointed chief water engineer of Rome. He immediately made a complete survey of the works and his report survives. From it and from the magnificent treatise by Thomas Ashby, giving the results of his archaeological work on the aqueducts of Rome, we know almost as much of the water-supply of Imperial Rome as we do of twentieth-century London. The first aqueduct to be constructed was Appia in 312 B.C., the last Alexandrina, A.D. 222–235. They mostly followed the contours and were very carefully graded; at Rome a fall of one in a

thousand is maintained over a distance of 10 miles, and in the provinces one in three thousand has been measured. In A.D. 97 the length of tunnels serving the capital exceeded 200 miles; but the raised stretches crossing valleys are, for obvious reasons, more familiar.

In the latter ventilation holes in the masonry were provided at intervals, while in the former shafts known as lumina or columnaria were inserted every 40 or 50 yards to prevent airlocks in the closed specus or water-channel. Where necessary settling tanks (piscinae) were arranged so that all sediment should be deposited before the water was distributed; at Rome two aqueducts, Virgo and Appia, needed no piscinae and another had none because the water was so bad that it was used only for naumachia (sham naval battles) and sewer-flushing. It was in fact a dirty-water main, like those recently introduced in London for fire fighting. Each aqueduct delivered its water into a number of castella or water-towers, from which proportionate amounts could be directed to the public fountains, the baths, and, as a minor consideration, to private users who paid a water-rate for a piped supply. According to Frontinus Appia served twenty castella, Anio Vetus as many as ninety-two. Some provincial aqueducts of the Roman Empire, such as the Pont du Garde at Nimes or that of Segovia, are more familiar, owing to their better preservation, than those of the capital: the Pont du Garde includes a well-preserved castellum with ten exits, but this could only have dealt with a small fraction of the total flow. Other important Roman aqueducts are known at Metz, Pyrgos near Constantinople, in Cyprus, where the city of Salamis had a huge reservoir served by one 30 miles long, Syria, Northern Africa, etc. The most complete account of those outside Italy is given by Alfred Leger in his 'Travaux Publics aux temps des Romains' (Paris, 1875), in which he gives particulars of ninety-five.

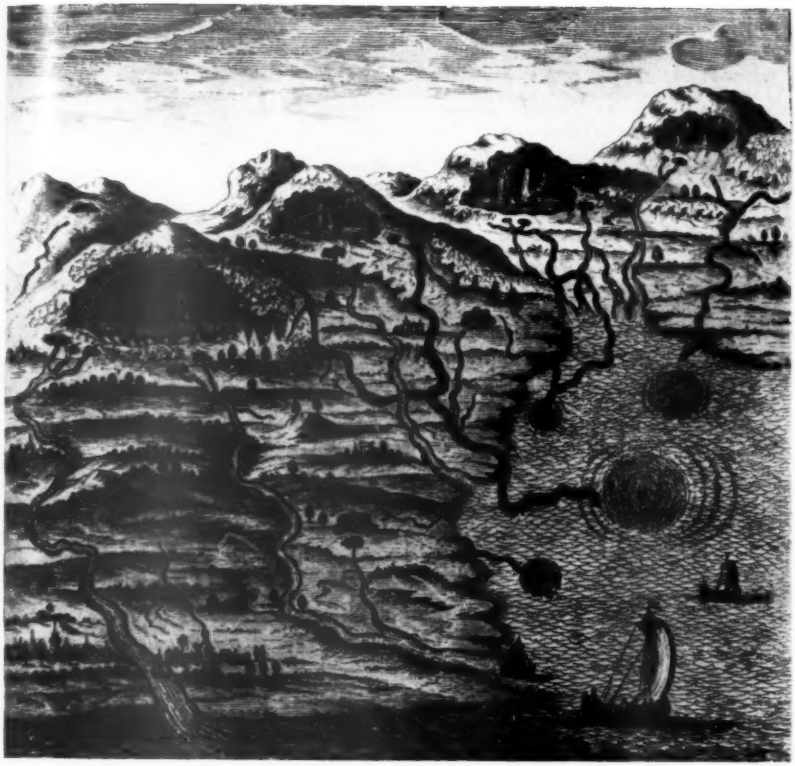
In Paris wells long sufficed for household use, but not for the public baths on the site of the Luxembourg: for these, water from a considerable area was collected and brought in by the Aqueduct de Rungis, mostly on arches. It was built about A.D. 360 under Julian, but largely destroyed by the Normans in the ninth century; its remains were utilized by Marie de Medici for her aqueduct d'Arcueil. The supply has been estimated at 2600 cubic metres (572,000 gallons) per day. Springs were also collected at Auteil and brought in earthenware pipes to baths near the Palais-Royal, but this supply only amounted to about 117,000 gallons.

In Britain Bruce has described an aqueduct cut in the hill sides, except for a very short embankment, which brought water from the Caw Burn to the station of Great Chesters on the Wall. The length is 6 miles, the distance $2^1/_4$ miles; since it lies wholly outside the Wall and several wells existed within, its purpose is doubtful; but it is a good bit of levelling, the greater part of its total fall of 30 feet being in a single step. There are other similar channels on the course of the Wall. At Uriconium many wells were filled in early in the second century. They had been superseded by a channelled aqueduct traced by Dr. R. L. Pocock from a dam on the Bell brook. This served the public baths and, from the amount of lead piping found, probably many private users as well. A similar channel brought water to the Roman Gold Mine at Gogofau, Carmarthenshire.

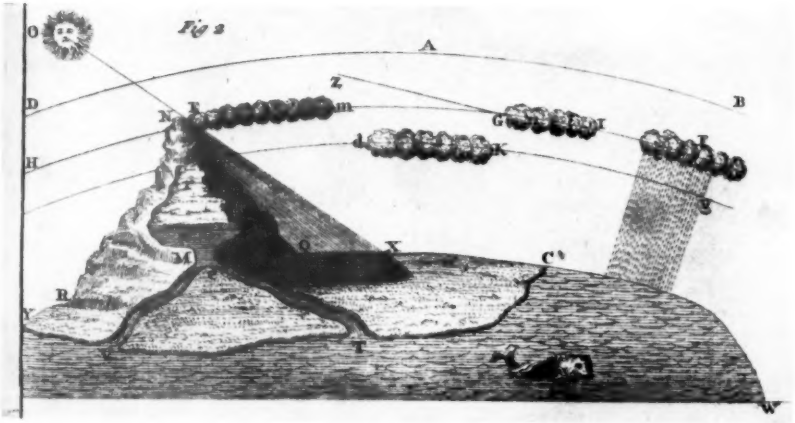
Since the masonry arches carrying Roman aqueducts across valleys and low-lying ground are conspicuous, some authors have argued that the principle of the inverted siphon was unknown at the time. Not only was the principle well known, but it had been applied centuries earlier, probably first by the Phoenicians; the difficulty lay in the construction of large-diameter pipes capable of withstanding pressure. At Pergamon an aqueduct dating from about 200 B.C. crosses two valleys on arches but over 60 feet below the general level. The actual pipes were probably of earthenware, but they were carried through perforated blocks of stone. At Patara in Asia Minor stone blocks, about 3-foot cubes, were bored with a 13-inch diameter hole and cut with projecting rings and recesses; the joints were cemented and also strengthened by iron clamps run in with lead. A similar stone is preserved at the Palestine Exhibition in Westminster. It formed part of an aqueduct from Hebron to Jerusalem; nearby was an inscription in Greek forbidding any ploughing within 13 feet of the aqueduct; lest anyone should be ignorant of the length of the Greek foot or podos a standard was also cut—its length is $12\frac{1}{16}$ inches. This aqueduct was built by a man whose name is more familiar throughout the world and throughout history than any other: Pontius Pilate.

The best preserved Roman siphon is the Pont-siphon de Garon which served Lugdunum (Lyon). It was built under Claudius in A.D. 50. The total length of the aqueduct is 52 kilometres, with eleven bridges, three tunnels, and three siphons: of the last, one crosses a ravine 66 metres deep on arches 16 metres high. The pressure of 50 metres of water on the pipes is equivalent to 62 lb. per square inch; there was a battery of eighteen lead pipes. Such pipes were made with sheet lead with a folded and burnt joint. The bursting of lead pipes is often referred to in familiar classical writers; and the further disadvantage from possible lead poisoning was well known. Vitruvius (VIII, 7) says that "water from earthenware pipes is much more wholesome than from leaden, because the water is so vitiated by the lead that whitelead (cerussa, not plumbum album which means tin) is produced"; this is said to be injurious to the human body. Paladius in 'De Re Rustica' recommends wooden or earthenware pipes for villa supplies, with lead where siphoning is necessary, though these may become poisonous. Bronze pipes were expensive but used for household supplies in Rome, Pompeii, and other places where rich men had great houses.

Earthenware pipes had previously been recommended by Pliny and are of course of great antiquity. Some Minoan pipes from Knossos are plain, but others, used where the line was curved, were supplied with two pairs of loops attached so that the cemented joint could be strengthened by external cording. Flanged earthenware pipes of the Harappa period at Chanhu-Daro in the Indus valley go back to the third millennium B.C. Pottery pipes with rectangular turns are known from the fourth century B.C. at Olynthus. In Britain, Roman lead pipes are fairly common and often carry inscriptions; earthenware pipes have seldom survived or been recognized, but they are known from Darenth, Folkestone, and a few other localities. A fine example of a Roman wooden pipe from the Bank is in the London Museum; it has an iron collar-ring to strengthen the joint and is of squared oak in contrast with the



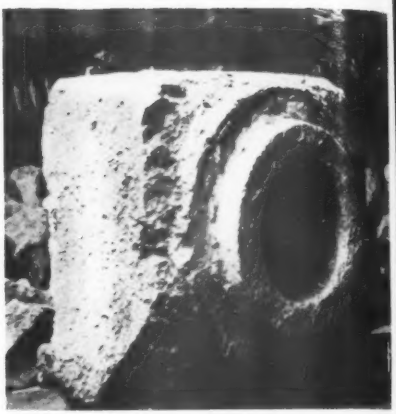
*1. Kircher's theory of springs*




*2. Halley's theory of springs*

Phot. G. Rodes

*3. Wooden pipe in Piccadilly, 1941*



*4. Stone pipe from Pilate's Aqueduct*

Phot. Rev. D. W. Darwell

*5. Brick-steined well at Corton*

eighteenth-century use of elm trunks. Some wood pipes found at Caerleon had been patched with lead plates.

Where an aqueduct was constructed to bring water from a neighbouring river it was frequently necessary to dam the river, both to preserve a constant level and to allow settlement of sediment in the resulting reservoir: a few such dams still exist. On the Orontes the Lake of Homs is a partly silted-up reservoir dating from the time of Rameses II (say 1300 B.C.). The site was well chosen at the northern outlet of a long flat valley; the dam was constructed of concrete faced with blocks of basalt; it is 20 feet high in the centre, 500 feet long, and raises the natural water-level by 16 or 17 feet, the resulting lake covering an area about 6 miles long by 2 miles wide. At Marib, in southern Arabia, there are remains of a dam dating from about 1000 B.C. An embankment across the Tigris at Assur, made about 1300 B.C. and some 5000 feet long, is interesting on account of the extensive use of bitumen as a waterproof cementing agent; the stone masonry is faced with brickwork laid in a bitumen mortar; the tablets recording the construction of the dam even state the site of the oil seepage whence the bitumen was obtained; full details with several illustrations are given in a brochure issued by the Shell Company. In the *Geographical Journal* for June 1940, Sir Aurel Stein described a Roman dam across a wadi near Hit capable of holding up 2 million gallons of water and so rendering fertile and habitable what is now a desert area. The late Roman dams near Constantinople were faced with white marble and sculptured. In the twentieth century many storage reservoirs add to the amenities of upland valleys, but the actual dams are not objects of beauty except to the eye of the engineer.

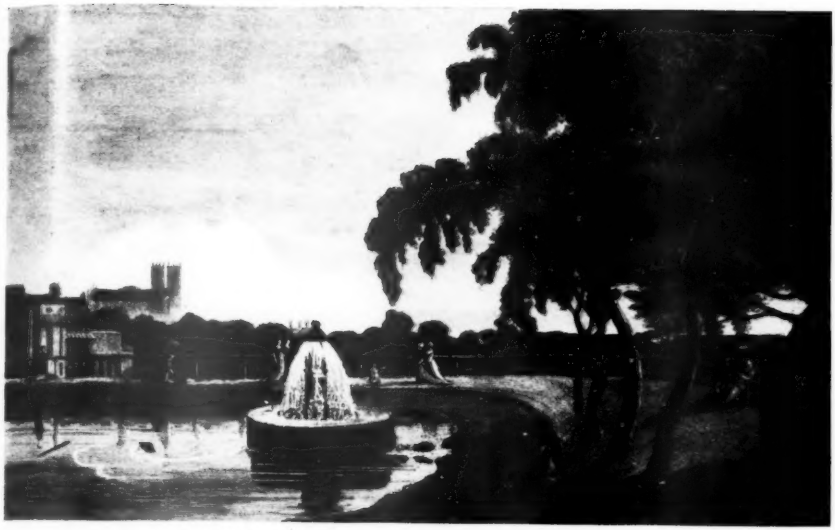
Before leaving the Roman period a word may be said about the surveying necessary for the layout of tunnels and the marvellously accurate levelling found in some aqueducts. In early times, the Egyptians used a right-angled isosceles triangle, suspended by the apex; a plumb-line showed the hypotenuse to be level when it cut it at the middle point, and measuring rods could then be sighted. Another instrument was the merket, a plumb-line in a case with a sighting slit, of which an example has been preserved. A later instrument was Hero's dioptra, which was essentially a water-horizon mounted with sights on a circle divided into 360 degrees; this division probably originated in Mesopotamia. An instrument approaching a plane-table has been reconstructed by C. L. Sagui (*Econ. Geol.*, XXV, 1930) from remains found by him in an ancient Greek mine at Mount Pangeon and from a carving on a block of stone re-used in the wall of the ninth-century church of St. Eleutherius at Athens. For most purposes the Romans were content to use a groma, an instrument which only served to lay down right angles. It consisted of a frame of two crossbars at right angles, balanced on a pivot; the four ends of the bars carried plumb-lines; the pivot was on an arm attached to the stand, so that the latter did not interfere with the lines of sight. This instrument was of course in constant use for the laying out of Roman camps and towns. Every legion had its own officer for the purpose, known as a mensor. The tombstone of a mensor, found in northern Italy, shows a simplified representation of the groma. Chance has preserved for us interesting evidence that accuracy could be attained with such instruments in the hands of an expert,

but that contractors were not always experts. In A.D. 152, a tunnel for water supply was to be constructed in Maŭretania; it was to pass through a mountain, and work was begun from the two ends simultaneously. The following is the consulting engineer's report to the local governor: "Nonius Datus, hydraulic engineer of the Third Legion, to the magistrates of Soldae [Algeria]. I began by surveying and taking levels of the mountain. I marked out most carefully the axis of the tunnel across the ridge. I drew plans and sections of the whole work, which plans I handed over to Petronius Coles, governor of Mauretania. And to take extra precaution, I summoned the contractor and his workmen and began the excavation in their presence with the help of the gangs of experienced veterans. . . . After four years' absence, expecting every day to hear the good tidings of the arrival of the water at Soldae, I arrive. The contractor and his assistants had made blunder upon blunder. In each section of the tunnel they had diverged from the straight line, each towards the right, and had I waited a little longer before coming, Soldae would have possessed two tunnels instead of one." Nonius Datus resurveyed the work and put in a transverse connecting tunnel.

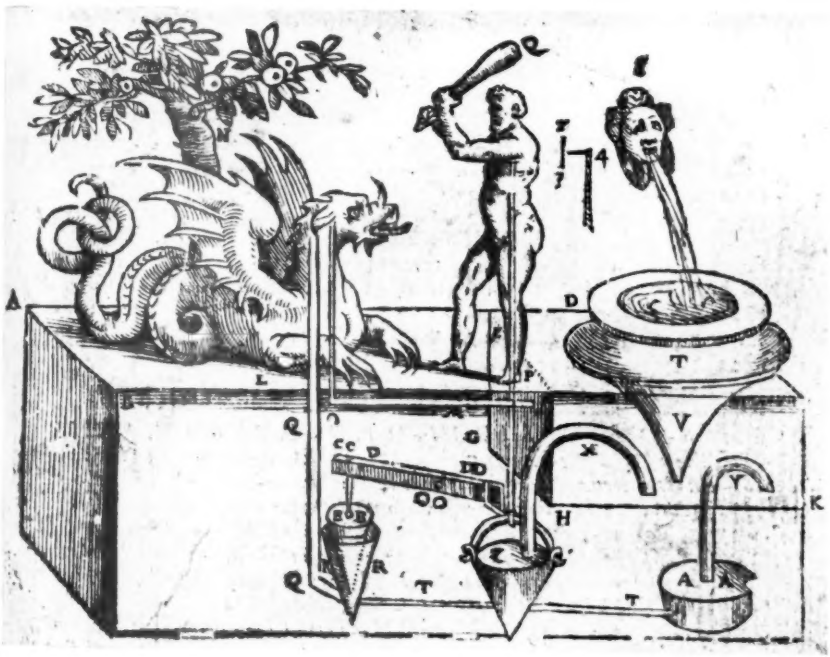
On the continent there is some continuity with the Roman tradition of water-engineering, particularly in the aqueduct method. In A.D. 541 Theodoric built an aqueduct at Spoleto; it includes a bridge 277 yards long and 438 feet high in the centre. The Moors built one in Spain at Elvas and at Constantinople Suleiman the Magnificent (1494–1566) not only repaired those built by Valens and Justinian but added another. A curious feature of these Turkish aqueducts is the souterazi, obelisk-like towers erected at intervals where the conduit crossed low ground with the water under pressure: at the top of each is an open cistern to which the water rises in lead pipes and again descends to ground-level, the heights being adjusted to the mean gradient between the intakes and the terminal underground reservoirs; they thus act both as air valves and as settling tanks. Here public baths on the Roman pattern also continued, some new ones being added by Mahomet II in the middle of the fifteenth century.

At Orvieto, where a public well had been sunk by authority in A.D. 982, an aqueduct to bring in the waters of the river Astiva was begun in 1273, finished in 1279, and a year later served the fountain of S. Giovenale; it was succeeded by a new one in 1865. In Malta one of the Grand Masters constructed an aqueduct at his own expense. There is one at Coutances dating from the fourteenth century, and many others could be mentioned.

Paris water-supply has an interesting history: as mentioned above, wells long sufficed for domestic supplies, but as early as the sixth century the Abbaye de St. Laurent got its water from the Pré-St.-Gervais. In 1082 Philip Augustus bought a fair from the Abbaye, together with a part share in the water: the new fair ground was Les Halles and the Fontaines des Halles, where the Rue Montmartre crosses the Rue Montorgueil, distributed the water. It was said to be superior to that of Belleville as containing less mineral salts; by taking such a precaution as the addition of potassium carbonate tied up in a bag it could be used to cook vegetables—a curious comment on the quality of supplies at the period. The date of the Belleville aqueduct is not known; several inspection chambers have the date 1457 on them, but that

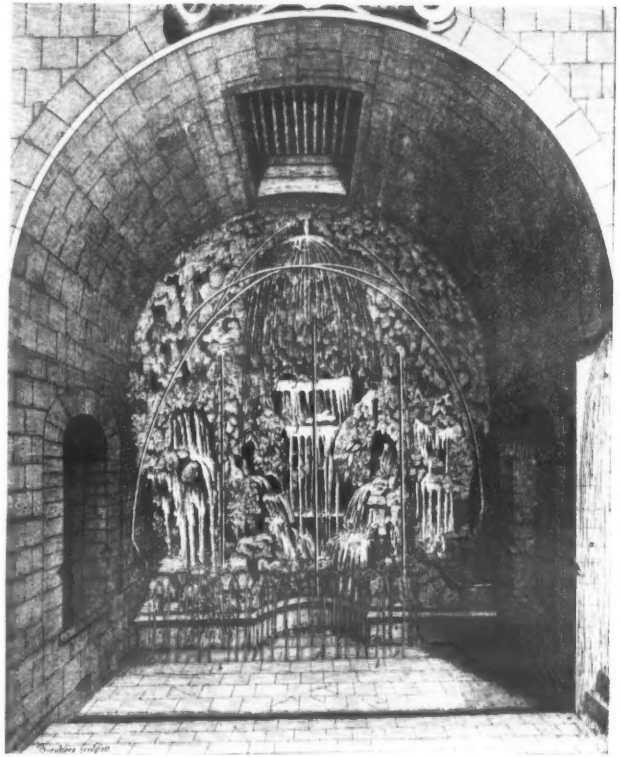


*6. The Green Park reservoir, 1807*




*7. Hero's use of siphons*

*8. Pumping machinery at Blenheim*



*9. Ornamental waterworks at Enstone*

*8. Pumping machinery at Blenheim*

*9. Ornamental waterworks at Enstone*

certainly refers to a restoration; one fountain that it served is described as old in 1320; it ran mostly in a masonry channel. The water is stated by Belgrande to contain 156 parts per hundred thousand of solids (a content of less than 15 is nowadays described as good, 15 to 50 as moderate). Many small projects for increasing the supply to the city followed, but despite laws and regulations the great lords and the monasteries absorbed most of the water. In 1553 the public fountains had to serve a population of about two hundred and sixty thousand and delivered only 300 cubic metres, barely over a quart per head per day. Henri IV (1553–1610) dealt with the situation with vigour: he approved the project for pumping Seine water, mentioned above, by the Pompe de la Samaritaine and set about establishing the aqueduct of Arcueil, but died before the project was realized. The first stone was laid on 17 July 1613, by Louis XIII, the water arrived on 19 May 1623, and reached the public fountains a year later. But again much water was diverted by the nobles, the Seine pumps were often out of order, and at the end of the century the public supply per head was reckoned at $3\frac{1}{2}$ litres, about 3 quarts per day. Projects to bring the water of the Yvette or of the Ourcq into Paris appeared in 1762: they were approved, amended, cancelled, revived constantly with no practical effect until Napoleon had the Canal de L'Ourcq constructed. He wished to kill two birds with one stone—how many inhabitants he killed cannot be reckoned—for instead of a mere aqueduct a navigable canal was made. In the course of 60 miles from the intake it picks up several small streams and ends in the basin of La Villette, 366 feet wide, ten times that in length, and 7 feet deep. It now seems hardly credible that for many years the great reservoir for public drinking water was also the sewer for one thousand five hundred boatmen living in the five hundred barges whose home it was. What would Frontinus have said!

We have seen that in Britain the Romans had no large-scale waterworks whose ruins would attract attention and suggest restoration; the first method adopted for supplementing local well supplies was independent of any link with the Roman epoch. This was the conduit system by which water from springs was collected in a conduit-head and conveyed by gravity, without siphoning, through pipes to the desired spot; here, if the supply was for public use, stood a fountain or standard, sometimes itself merely called the conduit. One is still in use in the market-place at Wells fed through a conduit by springs in the palace grounds. Conduit houses, of which several survive, were small buildings enclosing an open basin for inspection, erected at intervals along the pipe-line as required. The earliest record of a conduit seems to be a statement that the use of springs near the outfall of the Serpentine was granted to Westminster Abbey by Edward the Confessor, a monument with inscription to that effect stands on the spot; Canterbury Cathedral and monastery were supplied by conduit from A.D. 1150. The first public conduit in London brought springs from the banks of the Tyburn near the old Marylebone Town Hall in 1236. Also dating from the reign of Henry III is the conduit to Grey Friars, which is worth mentioning since the conduit-head where the waters of several springs were collected before entering the pipes still exists behind No. 20, Queen Square, Bloomsbury. Owing to the survival of detailed plans more is known about the Charterhouse con-

duit, dating from 1430, than any other. But so much information on London conduits is readily available that it will suffice here to point out that the early pipes were almost always of lead. They are constantly mentioned in the Great Chronicle; gifts of lead for this purpose are supplemented by fines to be paid in that metal; for instance in 1479 the Sheriff was guilty of unseemly language to the Mayor; he was condemned to provide twelve fodders of lead for repair of the conduits, which was later commuted to £51 sterling. Most big towns had similar conduits, as had such monasteries as needed them; the convent at Chester got a supply through 3 miles of lead piping in 1285.

The bringing in of larger supplies involving the use of an open channel did not begin with the New River in London, of which the first sod was cut at Ware in 1609, the water being delivered at New River Head in 1613. It was anticipated by Drake's Leat at Plymouth, begun in 1587 and finished in 1591; the distance from the intake in a stream to delivery was 7 miles, the length of the winding channel more than 20 miles; it was laid out by a Cornish miner who must have been a skilful surveyor or, in the language of the time, a cunning dialler. The work has been repaired as an emergency supply in war time. The New River was quickly followed by Hobson's conduit at Cambridge, which is the subject of a book published a few years ago. It was begun in 1610 and no doubt the famous carrier constantly watched the progress of Myddleton's work on his journeys between Ware and London.

Far earlier than either of these is an underground aqueduct at Exeter, recently investigated by the Devon Archaeological Exploration Society. It is known that in 1226 water from St. Sidwell's well was brought to the Cathedral Close through a passage partly hewn in native trap-rock and partly lined with masonry. It is even possible that the passages are of Roman date and brought the water of the well to supply a bath, but the evidence is as yet inconclusive. The free channel was later abandoned and the passage used for lead pipes. Underground water conduits also exist at Greenwich to bring supplies from Blackheath. There is evidence that some existed in the thirteenth century; it is certain that in 1434 Humphrey Duke of Gloucester and his wife Eleanor obtained a royal licence to make an underground conduit from a certain well called Stockwell across the highway to bring water from the well to their Manor or Inn. The existing Hyde Vale conduit passage goes from there to supply Greenwich Palace and certainly goes back to Tudor times.

It was not till the eighteenth century that wooden water-pipes became general, though earlier instances could be quoted. At Baden the nine public medicinal baths were supplied through "wooden pipes and trees" in 1685. In England they were normally of elm and of two types, perhaps indicated in the phrase just quoted from Dr. E. Brown. Untrimmed trunks were used, the small end being forced into the bore of the big end of the next length which had an iron collar inserted to prevent splitting; a good example of this type was exposed in a bomb crater in Piccadilly. The other form was in comparatively short lengths trimmed externally to uniformity. These are well shown in two drawings in the Soane Collection; they represent the New River Company's mains near the Fleet River at Battle Bridge (King's Cross). It is noteworthy that the parallel lines of pipes were laid on a prepared surface, not buried, where they traversed open fields, an arrangement which, while

making the pipes more liable to decay, made it a simple matter to repair leaks. About 1810 the company had nine trains of pipes side by side in one street, and the estimated loss from breaks and leaks was one-quarter of the supply. They were replaced by iron pipes in 1820, a fact which, combined with the introduction of steam pumping, may be taken to end the early history, as here discussed, as far as London is concerned. But in the country and abroad the date naturally varies; in Philadelphia it is recorded that there were still over 3 miles of wooden pipes of $4\frac{1}{2}$ inches diameter in the streets in 1847, though replacement by iron had begun in 1819.

We have traced in outline, using facts collected from sources too numerous to mention, the evolution of the marvellous water services of Imperial Rome and the subsequent fall which persisted till long after bored wells, steam pumps, and iron pipes introduced the modern period. A few comparative figures of the number of gallons per head per day of public water-supply are instructive; the estimates are probably as near correct as they can ever be:

| | *c.* 50 B.C. | *c.* A.D. 100 | 1823 | 1830 | 1835 | 1936 |
|---|---|---|---|---|---|---|
| Rome | 198 | 300 | | 250 | | |
| Paris | | | 3 | | | |
| London | | | 3 | | 10 | $35\frac{1}{2}$ |
| Manchester | | | | | $5\frac{1}{2}$ | 33 |
| Liverpool | | | | | $3\frac{1}{2}$ | $36\frac{1}{2}$ |
| Edinburgh | | | | | $7\frac{1}{2}$ | 52 |
| Glasgow | | | | | 12 | 57 |

It must of course be realized that some of these extraordinarily low amounts were not necessarily far below the demand. Muhammedans demanded, under religious obligations, bathing facilities comparable with the Roman, but our ancestors a few generations ago used little water for washing or drinking. The vast Marly waterworks were mainly to supply the *jets d'eau* and various ornamental fountains of the gardens of Versailles. Hobson's conduit was designed primarily to flush a ditch called the King's Sewer; drinking water was quite a minor consideration here, and at Plymouth Drake's Leat was partly intended to drive mills. Plot, in his 'Oxfordshire,' mentions a big spring at Somerton which "makes a small cascade or fall of water about 7 feet high; which were it not in the highway, but in a Gentleman's Garden some use might be made of it for divers good purposes, but as the case stands I think it can have none." Of Thame he writes "there is never a well in the whole town whose water will wash or (which is worse) brew . . . were they not supplied by the adjoining rivulet, the place must needs be in a deplorable condition." The waterworks of Enstone supplied a grotto in which, besides waterfalls, there were numerous booby traps to wet the unwary visitor and give him a bath willy-nilly.

Switzer's treatise on Water Works, apart from its mechanical and historical parts, is concerned with ornamental supplies; his plates show twenty-eight designs for fountains and artificial waterfalls; he hardly mentions domestic supplies, but quotes a letter concerning the uses to which water was put when actually brought into a certain Sir Thomas's house: "First it serves a

very fine Marble but unusual Beaufet to wash his glasses, and which will hold above nine Bottles at least half-way in water to cool his liquor. Secondly the next serves to turn the Spitt in his Kitchen by which, instead of a Jack and much more useful and less troublesome he roasts his Meat. Thirdly another large Cock in his Kitchen which serves all common uses in the same. Fourthly a Cock that turns in a Tubb to keep the Wort cool in the same to condense the spirits from a Bolt-head Still. Fifthly the next is the Brewhouse where it serves four Coppers . . . for Brewing. . . . Sixthly and lastly (at present) in his lower Kitchen it roasts his Meat (as in the upper Kitchen), churns his Butter, dresses the Flower for his Bread, washes his Cloathes, grinds his Malt. And now give me leave to add a seventh, upon the Anvil but not yet brought to Perfection, which will be necessary and very useful, being lately married to a fine young Lady, and which he is now contriving will be to rock the Cradle."

If the water-supply of some of our isolated villages and hamlets still leaves much to be desired, desired it is, and an adequate amount of pure water will eventually be provided for and used by all.

*Notes on the illustrations*

1. *Kircher's theory of springs* (1664). The woodcut illustrates the long-accepted idea that the water of springs is derived from the sea: the intakes are whirlpools, from which the underground channels leading to reservoirs within the tops of mountains are shown by dark lines; from these water issues as springs to form superficial rivers, shown by light colour, which may cross the course of an underground channel.

2. *Halley's theory of springs* (illustrated by Switzer, 1734). According to Halley, rivers originated in the sea, as required by scripture, but instead of underground channels, the sea water was evaporated by the sun, forming clouds, and was precipitated on the shady side of mountains. The water was again considered to collect in underground reservoirs before issuing as springs.

3. *Wooden water-pipe in Piccadilly*. This elm-trunk pipe was exposed in a bomb-crater early in 1941: an iron ring was inserted in the big end to prevent splitting when the small end of the next length was driven into it. It probably formed part of the Tyburn conduit dating from the thirteenth century, but the pipe is not earlier than the eighteenth. The modern pipes beside it are to replace others broken by the bomb, the wooden pipes having been out of use for more than a century.

4. *Stone pipe from Pilate's Aqueduct*. This aqueduct, constructed under Pontius Pilate, brought water from Hebron to Jerusalem. The stone pipes were used on account of the difficulties of manufacturing large-diameter pipes from any other material to withstand the pressure. This example was brought to England for the Palestine Exhibition in Westminster, to the authorities of which we are indebted for the photograph.

5. *Brick-steined well at Corton*. This well, near Lowestoft, exposed by coastal erosion, shows construction in successive sections from above downwards.

6. *The Green Park reservoir, 1807, looking towards Westminster*: the site is near the Tube Station. The reservoir was constructed about 1730 and received unfiltered Thames water pumped from Chelsea, which then served the St. James's and Whitehall area, still unfiltered. About 1830 filter-beds were introduced at Chelsea and the reservoir was cleaned and deepened, lined with brick-

work and enclosed by a wall topped with iron palisading, 9 feet high in all. Notice the dog swimming in the water supplied for drinking purposes.

7. *Hero's use of siphons.* Hero of Alexandria in the first century B.C. invented and described many curious water toys involving the use of siphons. The illustration is from an early Italian translation. In the text it is pointed out that the lower siphon (on the right) must have a smaller pipe so that the cistern continues to fill after the siphon has come into action. As the water rises the air is driven out of the cistern, causing the dragon to hiss before it spits water; the second siphon then causes Hercules to raise his club and hit the dragon on the head, after which the actions are repeated indefinitely, like the intermittent siphons now in use for flushing at regular intervals.

8. *The pumping machinery at Blenheim* (from Switzer) was a simple form of water-driven pumping installation similar to the larger and more elaborate works of London Bridge and Paris, driven by the little river Glyme at its entrance to the lake. The axle of the undershot water-wheel has three cranks at each side working rocking beams, each with a pump at both ends.

9. *The ornamental waterworks at Enstone*, from a plate in Plot's 'Oxfordshire' (1677). Besides the artificial waterfall in the grotto there are such devices as water-actuated singing birds and sundry means for wetting the unwary observer. It will be seen that the entrance to the grotto (on the right) could be covered by a curtain of water. In the eighteenth century much more water was used for such purposes than for ordinary domestic requirements.

## DISCUSSION

Before the paper the PRESIDENT (the Rt. Hon. Sir GEORGE CLERK) said: Mr. Bromehead is an officer of the Geological Survey who is professionally interested in water-supply and gave the Society some years ago an excellent paper on the "Influence of its geography on the growth of London" (*Geogr. J.* 60 (1922) 125–35), which dealt largely with the London water-supply. He has also antiquarian interests, and the Society will remember a paper Mr. Bromehead gave us more recently on ancient methods of mining (*Geogr. J.* 96 (1940) 101–20).

This afternoon he will combine his two sets of interests in a paper on "The early history of water-supply," a subject of great importance to students of historical geography, because some people are apt to overlook the ingenuity of the Ancients in overcoming the deficiencies of nature.

*Mr. Bromehead then read the paper printed above, and a discussion followed.*

The PRESIDENT: I hope that Mr. Cronin, Chief Engineer of the Metropolitan Water Board, will be good enough to speak.

Mr. H. F. CRONIN (Chief Engineer, Metropolitan Water Board): I should like, in the first place, to thank the Society very much for inviting me to hear this most interesting and entertaining lecture. I do not know that I can add much to it, but I have a few historical notes on the London water-supply which may be of interest.

Each year the Metropolitan Water Board publish an abstract of accounts. This is a public document, but not a best seller and not very interesting. In that abstract of accounts there appear some annuities and rent charges which have to be paid by the Board. They are as follows:

| | | | |
|---|---|---|---|
| London Bridge Waterworks .. .. | £3,750 | 0 | 0 |
| Hampstead Waterworks .. .. | £3,500 | 0 | 0 |
| Crown Clog New River Company .. | £400 | 0 | 0 |
| York Buildings Waterworks .. .. | £250 | 18 | 6 |

The lecturer gave some details of the London Bridge Waterworks which were eventually taken over by the New River Company in about 1822 when the Old London Bridge was demolished, the New River Company having then undertaken to pay annually the sum of £3,750 until the year 2082. The Metropolitan Water Board, as successor to the New River Company, continues the payment.

As to the Hampstead Waterworks, in 1692 the City Corporation granted a lease of the Hampstead and Highgate Ponds to the Hampstead Water Company. Subsequently the New River Company took over the Hampstead Water Company for an annual payment of £3,500. Those Ponds continued to supply water, not for domestic purposes, until 1936, when their use was discontinued. The water was supplied to the L. N. E. Railway at Kentish Town; to the L. M. S. Railway at King's Cross, and to the Metropolitan Cattle Market.

As to the Crown Clog of the New River Company, the New River was completed in 1613 by Sir Hugh Myddleton, who during the course of the construction of the river got into very serious financial difficulties. He applied to James I, who helped him on condition that the King should have half the shares in the New River Company. Subsequently, in the reign of Charles I, the New River Company's affairs were not prosperous and the King was persuaded to dispose of his moiety for an annual payment of £400 a year. That £400 is still paid by the Metropolitan Water Board to the Crown.

York Buildings Waterworks, which were situated at the bottom of Villiers Street and which were also taken over by the New River Company for an annual payment of £250 18*s.* 6*d.*, are interesting because they had a Savery engine installed in them. Apparently the engine was not a great success, for a Newcomen engine was put in about 1720.

It must be realized that in a city like London, where the sources of water are below the places in which it has to be delivered, the whole supply is dependent upon pumping, so that the history of waterworks in London is practically the history of the steam engine. In these days we hear much about economy in the use of coal, and that is impressed forcibly upon us when we are unable to get the coal we require. In that connection I should like to give some figures showing the relative coal consumption of pumping engines.

In 1712 a Newcomen engine required 23 lb. of coal per water horse-power hour. Newcomen improved his engine by 1776, reducing the consumption to 17 lb. Then came Watt, who reduced it to 12 lb. by the introduction of the separate condenser, and by further improvement in 1800 to 9 lb. In 1850 came the Cornish pumping engine, largely the work of Trevithick who, by raising steam power and other improvements, reduced the consumption to 3 lb. per W.H.P. hour. By 1900 we had the Vertical Triple Expansion steam-engine which required only 1·5 lb., and at present we have the Board steam turbines, which only use 1 lb. So that in about two hundred and thirty years the consumption of coal by pumping engines has come down from 23 lb. to 1 lb. per W.H.P. hour.

The water-supply to London, as is well known, was for many years in the hands of water companies: that is, until after the Metropolitan Water Board was formed under an Act of 1902. One of these companies was the Grand Junction Water Company, which started life as the Grand Junction Canal Company, which company was empowered to lay pipes and supply water from the Grand Junction Canal at Paddington. In 1811 these powers were transferred to a separate company, the Grand Junction Waterworks Company, which later moved their works from Paddington to Chelsea, where two Cornish engines were erected in 1820, having been built by Messrs. Bolton and Watt. In 1835 the Company, owing to the filthy state of the river at Chelsea, moved

their undertaking to Brentford, by Kew Bridge. They also moved the two Cornish engines, and those two engines are at present at Kew Bridge Waterworks. Over one hundred and twenty years old, they are still working and still supplying water. They do not work so frequently as in the past, but one of those engines, when it is working, often pumps water into the district in which the Society's building is situated.

The PRESIDENT: The hour is late and we must now close the meeting. Before I do so I am sure you will all wish to join with me in thanking the lecturer for a most interesting and amusing discourse.

*The following contributions to the discussion have been received:*

Mr. F. H. EDMUNDS (Geological Survey): A group of Roman wells at Cranborne Chase, near Salisbury, was described in 1887 by General Pitt-Rivers, with the observation that these were permanently dry; from which fact Pitt-Rivers justifiably concluded that during Roman times the water-table in the chalk of Cranborne Chase was higher than it is to-day.

A great number of the valleys of the Chalk country of the south of England are characterized by the occurrence of intermittent streams, variously known as bournes, lavants, woe-waters, and nailbournes. It has been assumed that early settlements were established along these valleys, since water was readily obtainable from shallow wells. If however the water-table was formerly higher than it is to-day, it may well have been that permanent streams then flowed in these valleys, alongside which settlements grew up. As the water-level dropped, the inhabitants may have dug shallow pits to maintain water supplies, and so have learnt the art of sinking wells through the necessity of maintaining contact with a steadily sinking water-table.

Mr. Bromehead has remarked that as far as water-supply is concerned we are now in the geological age. Unfortunately many people still believe that in order to get water from underground it is only necessary to sink a well; a belief which often proves to be most costly. Even among town-planning experts water-supply is often an afterthought. It is noteworthy that in the recent discussion on Regional Planning at the Royal Geographical Society this most important problem was completely ignored.

Mr. W. A. MACFADYEN: It may be of interest to recall certain ancient water-supply arrangements that are found in the Near East, particularly that ingenious method of getting a free-flowing stream in a dry land, the infiltration tunnel, known in 'Iraq as a *kahrez*, in Persia as a *qanat*. A well is sunk on rising ground by hand-digging to the water-table. The ground must be geologically suitable, for instance an alluvial fan, or hillwash. When water is struck, a series of shafts is sunk at intervals of about 20 metres in the direction of the proposed *kahrez*, and towards lower ground. These shafts are next joined up at water-level, the tunnel sloping only just sufficiently to cause the water to flow, and a trickle emerges as a surface stream at the *serechowa* or exit, which is often bricked over. The last stage of the work is to increase the flow by extending the head of the *kahrez* backwards more deeply below the rising water-table. A *kahrez* may thus be dug without any survey or levelling, the only requisite knowledge being that the water-table in the head wells is at a level sufficiently above the desired place of outflow. Its length is conditioned by this level and by the slope of the ground.

At that ancient town, Arbil, in 'Iraqi Kurdistan, the old *kahrez* which yields the municipal water supply is 5·5 kilometres in length, with some three hundred shafts along it, and the head walls are 48 metres deep. There are three branches at the head to increase the flow. The yield was about 250,000 gallons per day

in 1935; others may yield anything between perhaps 3,000,000 gallons per day (which was the largest of which I got an estimate) and nil.

Sir Aurel Stein (*Geogr. J.* 83 (1934) 124) has quoted the Greek historian Polybios to the effect that *kehariz* were in widespread use for irrigation in Persia at the time he wrote, about 150 B.C. Even at that date tradition ascribed great antiquity to their construction, connecting it with the beginning of Persian domination in the Near East. Stein's archaeological evidence proved their introduction in one district to be of post-chalcolithic date.

## TO THE SUMMIT OF TASMAN FROM THE WEST COAST

ALAN C. BROWNE

TASMAN is one of the most difficult and least climbed of all the New Zealand peaks, and when it is done from the west the climb is of particular interest. Except two huts, which of necessity are built on the most solid rock available, the whole of this climb is done on solid ice or frozen snow; from the moment one steps from the main forest of the west coast on to the clear ice of the Fox glacier at less than 700 feet above sea-level, to the summit at 11,475 feet, several days later. Where else in New Zealand, or perhaps elsewhere in temperate climates, is there a peak of similar altitude giving nearly 11,000 feet of continuous ice and snow?

My companions on the climb were Mr. H. K. Douglas, of Wellington (N.Z. Alpine Club), and that splendid guide, Frank Alack, both of whom were already two days up the Fox glacier while I was still photographing prospecting operations in the gold fields country at the back of Greymouth. Two days, as fast as service cars would carry me, took me through Hokitika to Weheka, where I found another guide, Newton Maxwell, waiting to carry a further load of provisions up to the top hut. Driving an old car as far as we could through an exquisite bush track, we left it, and, hoisting packs on to backs, we picked up our ice-axes and ropes and started on foot.

An hour's hot work through winding fern-covered track, under twisting vines and trees of scarlet *rata*, crossing creeks on moss-covered logs, brings one to the clear ice of the Fox glacier. It is hard to write of the lower altitudes of South Westland; nothing could do it justice. It must be lived with to be believed: seen when the first sunlight streams across the river beds and the ground begins to steam as the frost melts and the mist rises; when the bush resounds with the silver notes of countless bellbirds, and snowclad peaks rise from blue hills and tower into a clear pale-green sky; seen in a downpour of west coast rain, when the hills are hidden, the forest drenched, and all the countless ferns and mosses lift their heads again; seen as the sun sets behind a strip of dazzling sea and the great ice peaks turn from gold to blood red and fade to cold colourless ice as the mantle of night creeps across the sky. And yet, often as one may see these sights, see these great rivers of broken ice pouring down the valleys from unseen and unsuspected snowfields above the

*1. Fox glacier, Tasman, Cook, and La Perouse from Gillespies Beach*

*2. West coast road between Waiho and Weheka*

*3. Lower Fox glacier and Tasman from the route*

*4. Haast, Lendenfeldt, Tasman, and Torres from Pioneer Bivouac*

evergreen trees and ferns of the forest below, and simple as one knows the explanation to be, one cannot but stand repeatedly and gaze, feeling that somehow they cannot quite belong to this earth.

The first mile or so of the Fox is extremely easy going, it being, for a glacier, very flat and free from crevasses; in fact, so refreshing is the ice and so cool and invigorating the sunny air that travelling is a very real relief after lugging a heavy pack through the sweltering airless tracks of the bush. Later, to avoid the broken ice of the first icefall, one edges over to the right or south bank, and leaves the glacier to work up alongside the ice in a loose, broken, rocky gully known as Paschendale, so named on account of the bombardment of rocks varying in size from splinters to many tons in weight, which continually avalanche from the mountain side high above. Once through this gutter or corridor one again takes to the ice, almost immediately crossing the glacier to the left or north side, to where, nestling among the snowgrass on the skyline some 400 feet above the ice, can be seen a small speck: Chancellor Hut, with its two rooms and comfortable bunks at a height of some 4,500 feet. The steep scramble from ice up a rocky creek-bed and through a scrub-covered slope to the hut, is the only tiring part of a first easy day. Some months previously, when three of us crossed the Divide and went over to the Hermitage by this route, I had been fortunate in securing one of my best moonlight photographs from here. It showed Chancellor Hut in its winter conditions, surrounded by deep snow, the glistening icy river of the glacier far below winding its way down the valley to the lowlands, and in the distance the sea, with a great pathway of silver light from the full moon. Now I stopped to photograph some of the many clusters of alpine flowers which in the summertime take the place of the winter snow, and through which one must wade waist-deep to reach Chancellor Hut.

In so doing, I found the shutter of my camera jammed: the result of working in a deluge of water a few days before to secure flashlight photographs of the gold prospectors working at the bottom of a mining shaft far underground. Most of that night I spent with the camera, a needle, and the bottle of methylated spirit intended for use with the primus stove; and when we left Chancellor Hut at half-past three the next morning for Pioneer Bivouac the shutter was working again.

Dawn broke as we crossed the silent snowfields. Behind the thin grey silhouette of Tasman's great peak, tongues of flaming red cloud twisted and circled high into the sky against a grey leaden background that deepened to angry purple behind the peak itself. We plodded slowly on across the snowfields, working backwards and forwards among the crevasses which at that time of the year were beginning to open up. An hour or two later, aiming for the distant rocky spur which comes down from the peak of Douglas, and on which spur Pioneer Bivouac holds its precarious position, we saw a tiny figure and heard a shout: Alack coming across the snowfields to meet us. For an hour or so he had been watching us from his high vantage point on the rocks outside the hut. We met, and together the three of us toiled up the steep snow and finally the ridges of loose sliding rock to the highest and possibly the smallest building in New Zealand: Pioneer Bivouac.

Perched on its rocky ridge high above the snowfields, Pioneer Bivouac from

its altitude of 8000 feet commands a magnificent uninterrupted view round a third of the horizon. In the north, across the snowfields, peak after peak fades away into a blue haze, whilst down and beyond the twisting ice of the Fox glacier in the dim blue lowlands, tiny threads of silver can be seen: the Cook and Waiho rivers flowing into the Tasman Sea, whose far-distant horizon is surprisingly lifted high above a panorama of 7000-feet snowclad peaks.

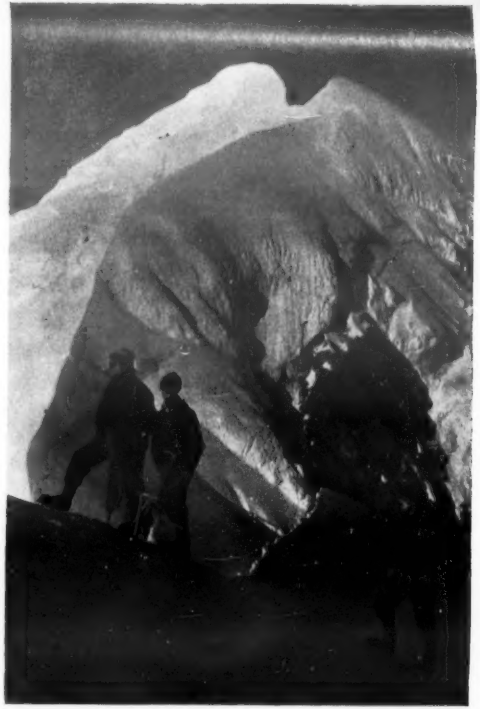
The Bivouac itself is about 8 by 9 feet, made of corrugated iron over a wooden framework, and lined inside with felting to keep in as much warmth as possible. As every piece of timber, every sheet of corrugated iron, and the whole contents of the Bivouac have been carried up on the backs of men, one cannot but appreciate the work that has been done in effecting so snug a shelter at 8000 feet. Windows there are none, and the doorway through which one must creep almost on hands and knees is about 3 feet 6 inches high, with a small rectangle of glass let in its centre so that the occupants of the hut can keep an occasional eye on the weather. Immediately inside the doorway is what might be described as the kitchen, where one man can just sit or stand while he prepares on the primus stove hot food or drink from the array of tinned food stacked at that end of the hut. Apart from this tiny space the interior of the Bivouac is simply one large shelf or bunk on which all lie together, each man wrapped in his grey blankets, his spare clothing forming a pillow. And so the time is spent reading or writing, and waiting for the weather. Here we found Douglas buried in the blankets, a stubble of beard and a plaster of zinc ointment on his face, completing his diary of the last days' climbs.

During that day the rain and sleet began, and increased in violence during the night, whilst showers of pebbles from high up on the loose rocky ridge above us occasionally peppered the flimsy tin roof of the Bivouac. Fortunately these pebbles were small, but each rattle was sufficient to make us speculate on the size of the next fall. The next day, Christmas Day, and a wild and stormy one, was celebrated with a spoonful of brandy in our evening coffee. Later the rain and wind eased off. We crept out of the hut on to the rocky ridge and saw the great peaks of Haast, Lendenfeldt, Tasman, and Torres bathed in crimson light as the sun slowly sank behind a sea of burnished gold. This promised well for the morrow and we prepared for an early start. Before turning in I tried to get a rough sketch of the scene. Wrapping myself in grey blankets I crouched out of the wind behind a big slab of rock, but paints froze on the palette, water froze in the bottle in my pocket, and the brushes froze stiff and would make no impression beyond scratching the paper. In the meantime Alack and Douglas were levering out of harm's way any of the rocks immediately above that were in danger of coming down and crashing through the hut in some future storm. That night two of us slept more peacefully, but a rock had crushed the forefinger of Alack's right hand.

The following morning we crept out of our warm blankets, breakfasted at half-past three by candle light, and at four-thirty in the grey dawn were on our way across the undulating snowfields to the foot of the Marcel glacier. In and out among the great green-blue walls of ice we worked our way, all the time climbing higher and higher until at last we stood in a gap on the skyline:

*5. Lower Fox glacier*

*6. Pioneer Bivouac*



*7. Tasman and the North Shoulder from Lendenfeldt*

*8. Looking back to coast from Haast*

*9. Looking up Great Tasman glacier from Haast*

Marcel Col, with the rocky buttress of Haast on our left and the steep snow slope of Lendenfeldt on our right. Several thousand feet below us lay the snow basin of the Grand Plateau, and towering high above on its far side was that great ridge of *Aorangi* the Cloud Piercer, Mount Cook, with the upper Linda glacier pouring from its high white cone. This sudden unexpected view of these towering buttresses and hanging glaciers as one gains the summit of Marcel Col is surely one of the most striking views of New Zealand's highest peak.

Beyond the Grand Plateau, beyond the Tasman glacier with its 16 miles of ice in the valley below, the eye could pick out the thin silver strip of Lake Pukaki, 40 miles away, whilst farther again the dim purple and blue of the Mackenzie Country faded into a bank of clouds over Timaru and the east coast. The view as one stands on these high places and gazes in every direction across endless ranges of snow peaks fading into the distance, to the sea on both sides of New Zealand, is beyond description. We swung to the right, and plodded silently up Lendenfeldt. But now a change began to take place. A bitterly cold wind started to whistle round us, and the higher we climbed up the steepening snow slope the stronger and more unpleasant grew the wind, until on the summit at 10,450 feet we could hardly stand as we saw heavy raincloud blowing up to us from the south-west. We turned and hurried back, stopping only long enough to take photographs of the wonderful towering ice blocks in the Marcel glacier. Thick wet cloud, drizzle, and sleet enveloped us as we found and retraced our quickly disappearing tracks across the snowfields and up the ridge to Pioneer Bivouac where, after hot soup, cheese, and bread and butter, we crept into our blankets and slept the rest of the afternoon.

Again the peaks were clear and brilliant in the sunset glow, so four-thirty the following morning (Thursday, December 27) saw three tiny figures, infinitely small, repeating their performance of the previous day, wandering across the snowfields, up the Marcel glacier to Marcel Col, pausing for a few moments, then up the steep snow slopes of Lendenfeldt. The summit was reached at 7.10 a.m., and this time not a cloud was to be seen. The early morning sun blazed across a sea of snow peaks and valleys, across far-away blue haze and distant sparkling sea, and there ahead of us towered Tasman; tremendous walls of silent green and white ice of the North Shoulder hanging like a colossal mantle over great perpendicular walls of precipitous rock. From Lendenfeldt Tasman seems but a stone's throw away. Unfortunately, to get there is not nearly so straightforward. From the summit of Lendenfeldt, where every moment counts, something like an hour or an hour and a half must be spent in cutting steps down the steep snow-face into Engineers' Col between Lendenfeldt and Tasman. Only then does one start up that white North Shoulder of Tasman itself, slowly moving and anchoring, cutting steps and creeping carefully upwards, working round towards the left or east to avoid the most precipitous part, hacking and cutting, pushing on again, until finally the slope flattens out and one lies down to rest on the top of a huge white dome. From the dome of the North Shoulder at 11,000 feet runs a narrow ridge of ice like the top of a high white tent, straight to that final pyramid, so sharp and steep, so perfect a finish to an immense peak.

Could we do it though? Was there time enough in the day to creep along that narrow ridge, up the final pyramid and back again to the North Shoulder, down to Engineers' Col, up Lendenfeldt again, down the far side into Marcel Col, down the glacier, across the snowfields and back to Pioneer? It was ten minutes past ten; earlier than we had imagined: not a cloud to be seen except away on the horizon over Greymouth and Hokitika, and not a breath of wind. We plastered fresh zinc ointment on our faces, readjusted dark goggles, and crept down to the narrow ridge. At an altitude of 11,000 feet this narrow ice arête, and the Silberhorn arête on the eastern side, which is even worse, are perhaps the chief reasons for Tasman being so seldom climbed. Many other more accessible peaks could be climbed with comparative ease in weather conditions that would make this high ice ridge of Tasman impossible. Step by step, three figures moved along the narrow ridge, always two stationary and anchoring while one moved forward a few careful steps. We reached the narrowest part, so narrow that for a few yards one could sit astride the ice edge, with a drop of some 3500–4000 feet to the Grand Plateau under the left foot, and some 3000 feet under the right foot to the west. Storms have gouged this ice on the western side into perpendicular funnels, and as one creeps along the top and takes a stealthy glance down, one's imagination is very ready to picture how night and day, for weeks on end, shrieking blizzards drive stinging ice and snow hurtling up those polished icy chutes and over that knife edge.

Suddenly there was a long, gentle, swish of an avalanche immediately beneath us. We grasped the ice edge and peered over to the left. Away down below a whole face of ice and snow was slowly sliding down and down, and a second or two later came a dull rumble and roar, and a cloud of soft white snow dust rose from the Grand Plateau 4000 feet below. Then Alack crept up, cutting steps as big as buckets through rotten surface ice into the hard ice beneath, pressing each step carefully with his foot before moving slowly into it; Douglas followed; we crept up and up, resting hands and axes on the steep snow slope as though climbing a ladder. The steepest was over; the slope began to ease off; steps were no longer necessary, hooked axes and spiked crampons gripped the icy surface; we stood up, balancing carefully at first, and shook hands on the summit of Tasman.

*Notes on the illustrations*

The photographs were taken by the author during the New Zealand summer of 1935–36, and give a picture of the route from the coast to the summit of Tasman which was reached on 27 December 1935. Where it is necessary to locate a point the distances in inches from the left hand and lower edge are given.

No. 1 was taken from Gillespies Beach (43° 25′ S. 169° 49′ E.) on the west coast looking towards the Southern Alps only some 20 miles distant. The three highest peaks are from left to right, Mount Tasman (11,475 feet), Mount Cook (12,349 feet), and La Perouse (10,101 feet). The hut in the foreground belonged to a gold digger.

No. 2 was taken on the way from Waiho Gorge (the Franz Josef glacier) to Weheka (the Fox glacier), and is typical of South Westland roads.

No. 3 was taken from the road looking towards Tasman. The Fox glacier, some 4 or 5 miles distant, can be seen in the valley at 2.2, 2.2. The summit of

Tasman, 3.0, 3.3, is some miles beyond, with Mount Lendenfeldt (10,450 feet) 2.5, 3.1 and Haast (10,294 feet) 2.2, 3.0 to the left.

No. 4 was taken looking south-west from Pioneer Bivouac. The peaks are from left to right, Haast, Lendenfeldt, Tasman, and Torres. The author climbed the Marcel glacier, 1.4, 2.3, to Marcel Col and thence to Lendenfeldt, Engineer's Col 1.7, 2.8, the North Shoulder 2.2, 3.2, and Tasman summit 2.3, 3.2.

No. 5 looks south-east up the Fox glacier, showing the lower six of the $8\frac{1}{2}$ miles of the glacier. In the left foreground there is the Kaiserin Victoria range and in the left distance the Chancellor ridge with the Chancellor hut at 1.5, 2.7. To the right there is the Fox range.

No. 6 shows Pioneer Bivouac (8000 feet) 0.9, 2.5, on a rocky spur of Douglas Peak (10,107 feet) with parts of the névé of the Fox glacier in the left centre and in the foreground.

No. 7 was taken at 7 a.m. from Lendenfeldt and shows the summit of Tasman to the left, and the North Shoulder. The author climbed Tasman from the west by Lendenfeldt and the North Shoulder. Compare his account with the observations of E. A. FitzGerald, the first climber of Tasman (1895), who approached from the east. FitzGerald, describing the view from the summit of Tasman, writes: "If it were only possible to gain the arête which leads from Mount Lendenfeldt to where we stood, it would prove both an easier and a safer method of reaching the summit than the route by which we had come. Great and perhaps insurmountable difficulties however would lie in the way of gaining this arête, which would practically involve the ascent of Mount Lendenfeldt by its east face. This would be not only a difficult but also a dangerous climb, though, I believe, perfectly possible." FitzGerald, like the author, had to make two attempts on Tasman owing to bad weather.

No. 8 was taken from Haast at 6 a.m. looking north-west towards the coast which can be seen in the centre of the picture from 0.0, 2.3 to 4.7, 2.5. On the left at 0.5, 1.6 is the head of the Great Icefall of the Fox glacier, with parts of the snowfields which supply the glacier stretching across the middle distance and immediate foreground. The indentation of the coastline at 2.7, 2.4 is the mouth of the Waiho river flowing from the Franz Josef glacier, and the conical peak at 3.6, 2.5, Mount Moltke (6521 feet). The horizon of the Tasman Sea stretches right across the photograph from 0.0, 2.9.

No. 9 was taken looking north-east from Haast. In the foreground there is the Needle of Grey, 1.6, 1.4, with Mount Haidinger (10,059 feet) 0.9, 3.0, behind, and D'Archiac (9279 feet) 2.3, 3.0, Darwin (9715 feet) 2.6, 3.0, and Malte Brun (10,421 feet) 4.7, 3.1 to the right. The upper reaches of the Great Tasman glacier are seen flowing (top left to bottom right) down the valley some 5000 feet below. The Malte Brun hut is at approximately 3.3, 2.0.

# REVIEWS

## EUROPE

PLACE-NAMES OF MIDDLESEX, APART FROM THE CITY OF London. By J. E. B. Gover, A. Mawrer, and F. M. Stenton, with the collaboration of S. J. Madge. (English Place-name Society, vol. XVIII.) *Cambridge: University Press*, 1942. 9×5½ *inches;* xxxiv+238 *pages; maps.* 18*s*

This volume follows the well-established plan of the publications of the English Place-name Society, and has been compiled despite the dispersion of materials due to present conditions, which however have enforced delay in treating the names of the City of London. The present county of Middlesex is a remnant only of the territory once the kingdom of the Middle Saxons, extending from southern Hertfordshire into Surrey, and westwards to the Chilterns. Unlike its powerful neighbours it never came under the control of a competent ruling house, and by the sixth century it had with London been absorbed into the East Saxon kingdom. The early date of the Saxon settlement is abundantly evidenced in the surviving place-names, which embody a few Celtic river names, but no traces of Scandinavian influence, and relatively few Anglo-Norman forms. The plain in the west of the county retains traces of early tribes in the names Yeading (Geddingas) and Ealing (Gillingas), and the neighbouring Harrow is derived from "gumeninga bergae," heathen shrine. A further suggestion of sanctity attaching to this district is afforded by the derivation of the river name Brent from the old British "Brigantia," meaning holy. The distribution of early names as a whole, with the predominance of forms implying woodland or clearing in the north and north-west, illustrates the progress of settlement. A useful feature is the inclusion of lists of modern street and other names which preserve associations which would otherwise have disappeared with the spread of the London suburbs. G. R. C.

## ASIA

NORTH OF SINGAPORE. By Carveth Wells. *London: Jarrolds*, 1941. 9½×6 *inches;* 256 *pages; illustrations and end-paper sketch-maps.* 18*s*

Mr. Wells writes of a journey from New York westwards round the world during the latter part of 1939, with accounts of his experiences in Japan, Korea, and Peiping, to which he and his wife paid brief visits, and, in particular, of their subsequent stay in Malaya of which he had already had some considerable knowledge. It would appear that the main object of Mr. Wells's journey was to vindicate an assertion made by him that he had, in Malaya, "seen fish climb a tree and deliberately wink its eye." In view of this the reviewer has consulted two specialists about Chapter XI, "Sea snakes and tree-climbing fish" and is advised that : "It is clear from his description that the so-called sea snakes are not true sea snakes but land snakes (Homalopsinae) that take freely to water, even sea water, to obtain their food. The habits of sea snakes are quite different from what he describes. The Homalopsinae are fairly common in the estuaries of the Malay Peninsula."

"With regard to his tree-climbing fish, the facts are in the main accurate, but perhaps somewhat exaggerated. The fish shown in his photographs is the well-known and widely distributed Mudskipper (*Periophthalmus*), found on most tropical coasts, especially near mangrove swamps. It walks or jumps about on the mud-flats at low tide, and is very fond of basking in the sun. It climbs out on to the mangrove roots themselves, and this probably represents the summit

of its so-called tree-climbing activities; it may get on to the lower branches of trees, but this is very doubtful; what are described as branches are probably mangrove roots. The fish is adapted for living out of the water by having gill chambers which can be kept full of air. The pectoral fins are specially modified to form something like muscular arms, which can be moved like limbs, and on land the fish is said to be as agile as a lizard. The eyes, on the ends of protuberances, can be turned in every direction. One may doubt however the author's assertion that when swimming it keeps its head out of water and looks where it is going."

"Another fish, the famous Climbing Perch (*Anabas*), known throughout the fresh waters of the East, crawls on land in damp places, especially after storms, but in quite a different way from the Mudskipper. It has been found in the forks of trees, probably captured by kites and placed there to be devoured at leisure."

Considered as a light travel book, 'North of Singapore' will probably have a wide popular appeal, for despite some curious grammar, Mr. Wells writes attractively and has the gift, so valuable to the travel writer, of taking his readers with him. His accounts of what he saw and did in Japan and North China during the summer of 1939 are of interest to the student of world affairs.

E. H. DE B.

## NORTH AMERICA

AMERICAN GUIDE SERIES. New York; a guide to the Empire State: xxxi+782 *pages;* and Michigan; a guide to the Wolverine State: xxxvi+682 *pages*. Compiled by workers of the Writers' Program. *New York: Oxford University Press*, 1941. 8×5½ *inches; illustrations and maps.* 16*s* 6*d each*

These are two further noteworthy publications of the Federal Writers' Project. This scheme has achieved both remarkable social and geographical results; for it has not only enlisted the work of a great many unemployed in America, but each Guide is in itself comprehensive, interesting, and packed with information. While the word "Guide" seems optimistic, not to say ironical in these times when travel is at a minimum, nevertheless these books are a refreshing distraction and may well be "so many useful and interesting finger-posts for one's own American journey." The first-hand local descriptions and recent statistics of the introductory chapters are invaluable and not easily obtained elsewhere. In addition to the hints to travellers on routes and rules, health and hygiene, Part I (General Background) covers every aspect of the State from geology to history, folklore to industry, and architecture to social services. Though this regional survey is solid with facts, yet it captures much of the local intimacy which must appeal strongly to the American reader and which might be supposed lacking in an account of such large States (Michigan is nearly 100,000 square miles, including water, and New York over half as big). The chapters on Marine Lore in Michigan, Folklore in New York, and Archaeology and Industry in both States are some of the best.

Parts II and III of both books (Cities, and Tours, respectively) are inevitably less interesting to English readers than Part I, but they form an integral part of the Guide and are useful for reference. Pretension and advertisement are not wholly avoided but are partly justified where the scenery is undeniably grand and varied and material progress is almost unparalleled. The style is generally good and readable, although one would prefer to be spared Michigan's epithet of "The Wolverine State." Illustrations are many and excellent, and there are appropriate maps in the text as well as a large folder map of each State.

M. J. B.

## PHYSICAL AND BIOLOGICAL GEOGRAPHY

INTRODUCTION TO GEOLOGY. By E. B. BRANSON and W. A. TARR. Second edition. *London and New York: McGraw-Hill Publishing Co.*, 1941. $9\frac{1}{4} \times 6$ *inches;* x+482 *pages; illustrations and diagrams.* 26*s*

Some years ago Professor S. J. Shand published a book called 'Geology without jargon,' a phrase which might well form a sub-title to this stimulating book. It sticks to simple language with few lapses, and tells the geological story comprehensively. The composition of the earth's crust, its upbuilding, and its decay are the subjects of the first part which is well illustrated with pictures which have not become hackneyed through over use. The second part deals with the historical aspect of geology and is treated in such outline that the main features of geography of past periods of North America are clearly stated and no superfluous details confuse the story. The course of evolution is sketched from the earliest times to the present, an admirable peculiarity being that the illustrations of the various fossils concerned are displayed without even generic names to burden the memory, except in the case of some of the saurians and mammals. The whole strikes a nice balance and the tone of the book recaptures some of that romance which made geology a popular subject fifty years ago, before a public became sickened by dull discourses involving more and more detail about less and less.

Outstanding points are many and the method of treatment of some parts of the subject refreshing. A diagram shows how weathering of felspar goes on and provides soil with potash in it. The development of valleys is illustrated from the hills and plains to mature valleys with ox-bows or flood-plains lying below the river held up by levees. The review of glacier work and the formation of sheets of drift is excellent and ranks high as a piece of convincing description. Sand dunes are formed by wind action, as every one knows, but knowledge that the type of dune is related to the amount of material at the disposal of the wind is restricted to the few until they read this chapter. Faults are made more interesting by stating at the outset their effect on ore veins and coal seams or in earthquakes without too many hypothetical sketches, and an unusual aspect of folding and jointing is provided by considering the effects on tunnel construction. The appalling mortality occasioned by earthquakes is listed for several disasters old and new, the worst being one which occurred in China in 1556, when 830,000 people lost their lives.

There is not much space allotted to speculation; isostasy and continental drift are not mentioned; rival hypotheses of origin of the earth are explained and their features tabulated simply. The time when life began is put back a long way before the Cambrian, indeed the authors' list has no period which they consider was lifeless. The objective study of the elements of stratigraphy from the brink of the Grand Canyon seems very sensible, whilst the changes in types of marine sediments from place to place are illustrated effectively by a diagram showing map and section in relation to each other. The evolution of the vertebrates is more to the front than that of the spineless animals, because the big reptiles and mammals appeal more to the imagination than do the minute foraminifera, although their evolution is at least as easy to trace.

Economics are never lost sight of. Each geological process and each age is bracketed with its application to the crafts, and now and then the reserves of some mineral or stone in one of the periods are noted. The climatic changes throughout these intervals are referred to briefly. The index is adequate, but a few references to books to allay the curiosity which this admirable introduction stimulates might have been included. J. V. H.

# THE MONTHLY RECORD

## PERU–ECUADOR BOUNDARIES

In accordance with Article 8 of the Protocol signed at Rio de Janeiro, 29 January 1942, and since ratified by both Congresses, the boundary line has been determined by the following: In the west Boca Capones on the Pacific, the river Zarumilla upstream and the ravine Balzamal or Lajas; the river Puyango or Tumbes downstream as far as the ravine Cazaderos; the ravine Pilares and Alamor as far as the river Chira; the river Chira upstream, the rivers Macará, Calvas, and Espindola upstream as far as the source of this latter in the Sabanillas cluster of mountains; from the Sabanillas cluster as far as the river Canchis in its whole course downstream; the river Chinchipe downstream to the point at which it receives the river San Francisco east of the ravine San Francisco. In the east the watershed between the rivers Zamora and Santiago as far as the confluence of the river Santiago with the river Yaupi; a line to the confluence of the river Bobonaza with the river Pastaza, then a line to the confluence of the rivers Cunambo and Pintoyacu forming the river Tigre, then a line to the confluence of the river Cononaco with the river Curaray; the river Curaray downstream as far as Bellavista; a line to the confluence of the river Yasuni with the river Napo; the river Napo downstream as far as the mouth of the river Aguarico; the river Aguarico upstream as far as the confluence of the river Lagartococha or Zancudo with the river Aguarico, the river Lagartococha or Zancudo upstream to its source and thence a straight line meeting the river Gueppi and from this downstream as far as its mouth on the Putumayo, and from the Putumayo upstream as far as the boundaries of Ecuador with Colombia.

Article 9 of the Protocol provides that the line described above will be accepted by Ecuador and Peru for the fixing of the boundary between the two countries on the ground by the experts. Nevertheless, in proceeding to its demarcation on the ground, the parties may agree to such reciprocal concessions as are considered suitable for the purpose of adjusting the line in question to geographical realities. The said rectifications shall be effected with the collaboration of representatives of the United States of America, the Argentine Republic, Brazil, and Chile.

In the south the disputed region in Tumbes has been divided, the Peruvian maximum claim stretched almost to Machala, the Ecuadorian to the river Tumbes. We may note that on Wolf's map of Ecuador (1890) the "Lindero como existe actualmente de hecho" must very nearly be the present boundary in Tumbes. The Macará, Calvas, and Espindola had more or less been accepted by both Peru and Ecuador as the boundary. In Jaen the claim of Peru has been recognized. In the east the disputed region of the Oriente has been divided, the boundary crosses the main rivers, Morona, Pastaza, Tigre, and Curaray just above the limits of navigation, but in the north Ecuador has access to a navigable portion of the Napo and a stretch of the Putumayo.

## NEW ZEALAND GLACIER STUDIES

In a "Note on the Franz Josef glacier, December 1940" (*Trans. Proc. Roy. Soc. N.Z.* 71 (1941) 128–33) Mr. R. Speight discusses its present state. In an earlier publication (*Trans. N.Z. Inst.* 1935) he noted the position of the front as recorded at various dates since 1894, and found that the ice after having remained almost stationary between 1894 and 1909, retreated till 1921, and then

advanced. Between 1934 and 1938 there was some retreat and lowering of level followed since then by a very marked retreat. There is now evidence of a rise in level in the upper portions of the glacier which is likely to produce an advance at the ice-front before very long. The recent abnormal decline of the Franz Josef glacier has also been shown by the Fox and Tasman glaciers, and a comparison is made between the importance of the different factors of wastage for the three ice-streams. The lower parts of the Fox and Tasman glaciers particularly have collapsed in a remarkable manner behind a relatively stable front, because of inroads on the main body of the ice by the glacial stream which has left channels, tunnels, and sink-holes. These two glaciers are in places heavily masked by moraine through rock falls from the valley walls, unlike the Franz Josef glacier where the ice is more exposed to direct sun-heat. The author concludes that if the New Zealand Alps are compared with the European Alps, sun-heat is relatively unimportant and that rain is more effective, since in swelling the glacial streams it both melts and erodes, and may even cause collapse of the glacier surface. Unfortunately, Mr. Speight's references to the meteorological factors are confusing, as he fails to make the vital distinction in this context between rain and snow as components of the "rainfall" or total precipitation at different levels. The statement that in parts of the New Zealand Alps a rainfall of 200 inches a year comes chiefly in summer is erroneous, since statistics show little seasonal variation, and even more erroneous is the statement that in the European Alps summer rains are exceptional, for Switzerland has the rainiest summer climate on the continent. If it is implied that the lower parts of the Swiss glaciers, which may not descend so far below the general climatic snow-line as those of New Zealand, are little exposed to summer rain as distinct from snow, this should be so stated.

It is pointed out that though the strength of subglacial streams and their reinforcement by rain may account for some of the ablation this would not explain why all three glaciers retreated so rapidly after 1938. The obvious suggestion of diminution of snowfall during a succession of seasons is held insufficient reason because, although snow conditions on the divide are similar for all the glaciers, the Tasman is longer and of more gentle grade than the others, and hence should show the effect in its lower reaches much later.

In the December number of the same Journal Mr. Speight contributes another paper discussing evidence for the extension of the Rangitata and other glaciers for several miles on to the Canterbury Plains beyond the outlets of the present river gorges at the height of the Pleistocene glaciation. There is also a contribution by Mr. C. A. Cotton on the moraines and outwash of the Tasman glacier in relation to the features of the valley and the shrinkage of the glacier now in progress.

## THE WORLD IN TWO STRIPS

The *Philosophical Magazine* for November 1941 has a brief note "The World mapped in Complementary Segments," of which a reprint has been sent us by the author, Mr. A. F. Dufton. The partition of the world's surface is that used in making the cover of a lawn tennis ball: it is not new, having been employed by Professor Rosen for map 45 of the Nordisk Världsatlas, published in 1926. Professor Rosen represented the two complementary areas at right angles to one another on equal area cylindrical projections with parallels 30° of true length. Mr. Dufton also uses an equal area projection, defined obscurely as "the scale of longitude aptly proportioned to the cosine of the latitude augmented by two." This ingenious partition of the world, by making the world-map of two strips at right angles with rounded ends, seems to be more curious than useful.

## HALLEY'S TIDAL CHART OF THE ENGLISH CHANNEL

In our review of Professor Chapman's pamphlet 'Edmund Halley as physical geographer' (*Geogr. J.*, November–December 1941) we referred to Halley's Tidal Chart of the English Channel, which had escaped the notice of Professor Chapman. A fine copy of this chart in two sheets had been acquired by our Society in 1938, and so far as we know this is the only copy surviving of the original edition, engraved by Mount and Page and published probably in 1702, following Halley's survey made on his third voyage in command of the *Paramour* in the summer of 1701. A small edition of a full-sized reproduction in two sheets by photolithography has now been made, and copies have been distributed to a certain number of principal libraries and learned societies. A few copies are available for sale and can be obtained from the Society.

## ADDITIONS TO THE LIBRARY

In the March *Journal*, p. 159, some details were given of books recently added to the Library. This note records articles in periodicals received within the last few months which deal primarily with physical geography. It is convenient to refer at the outset to the appearance of a new Spanish geographical periodical, as the articles it contains are mostly concerned with that branch. *Estudios geograficos* is published by the Instituto Español de Geografia of Madrid, under the auspices of the Consejo Superior de Investigaciones Cientificas, and its purpose is stated to be the demonstration of the share of Spain in the progress of geography during recent centuries. In the four numbers received are two papers on the geomorphology of the Pyrenees: by N. Llopis Llado on the karst massif of Garraf west of Llobregat and by L. Garcia-Sainz on erosion surfaces of the central Pyrenees prior to the quaternary glaciation; a paper on the hydrography of the peninsula by A. Revenga Carbonell, and another on aridity and endorism in Spain by J. Dantin Cereceda. There are also a number of others on historical and human geography.

The first systematic attempt to determine the limits of quaternary glaciation in the Cordillera Oriental of Colombia is contributed by V. Oppenheim to the *Revista* of the Colombian Academy of Sciences (No. 13 (1940) 70–81). He distinguishes three levels at 3200; 3500; and 4100 metres, and includes a sketch-map of these levels in the Paramo de Sumapaz. In *Spolia Zeylanica* (vol. 23, pt. 1, 1941) Dr. D. N. Wadia publishes four articles on the geology of Ceylon, emphasizing the contrast of this ancient land surface, unsubmerged since Cambrian times, with the recent forms of the Himalayan region where most of his previous work had been carried out. His description of the ring of waterfalls in central Ceylon, which descend the fault scarp of the interior horst, affords a preliminary survey of recent earth movements. A point of general theory is raised by R. M. Mahard in an article in the *Journal of Geomorphology* (5 (1942) 32–44) which suggests the necessity for caution in assuming that all entrenched meanders necessarily afford evidence on stream rejuvenation or the nature and rate of land uplift.

In the Clarke Memorial Lecture delivered by C. A. Sussmilch to the Royal Society of New South Wales (*J. and Proc.*, 75 (1941) 47–64) the geological evidence for changes of the climate of Australia in past ages is summarized, and the agreement of the conclusions with similar studies for other parts of the world indicated, without an attempt to discuss the causes. Another publication of interest, but dealing with a recent phenomenon, is the account of the great West Indian hurricane which struck Long Island and New England in September 1938 (*U.S. Geol. Survey*, Water supply paper, No. 867). This is described as "the greatest catastrophe in New England since its settlement by the white

man." In the central area, the rainfall was as much as 17 inches locally, the average being 11·5 inches, and the direct run-off reached 9 or 10 inches.

The systematic classification of the properties of Irish soils is begun by P. H. Gallagher and T. Walsh in the *Proceedings of the Royal Irish Academy* (vol. 47, B, No. 8, 1942). This paper treats of soils with comparatively free drainage, and gives analytical data for profiles of ten groups representative of the most important types occurring in the country. Though most are derived from transported glacial drift, a relationship can in most cases be established with the local geology.

## OBITUARY

COLONEL MAURICE O'CONNOR TANDY, D.S.O., O.B.E., late R.E.

Colonel Maurice Tandy, who died at Oxford on April 18 at the age of sixty-eight, after a brief illness, had spent most of his service life in the Survey of India, in which he rose to the rank of Director; and on retirement from the Army in 1928 he became Instructor in Surveying in the University of Oxford. He had seen active service in the Aden Hinterland in 1902–04, in the war of 1914–18 in Europe and in Mesopotamia, for which he received the D.S.O., and in the Afghan War of 1919. He represented India at the second international conference of the International 1/M Map, which met at Paris in December 1913, and his few surviving colleagues of the British delegation have a lively remembrance of his ability on that occasion. For twelve years at Oxford he taught survey to successive generations of students, and retired in 1940. He had been a Fellow of the Society since 1920.

## MEETINGS: SESSION 1941–42

Seventeenth Meeting, 2 March 1942. The President in the Chair

*Elections:* Dr. E. G. Essery; Captain A. J. Maitland-Makgill-Crichton; Lieut. Herbert H. Nuttall, R.A.S.C.

*Paper:* Projects for the Alaska Highway Route. By Capt. G. S. Andrews, R.C.E.

Eighteenth Meeting, 9 March 1942. The President in the Chair

*Paper:* The Survey of Sarawak. By Capt. D. L. Leach, R.E.

Nineteenth Meeting, 16 March 1942. The President in the Chair

*Elections:* Mrs. A. Longton Thomas, M.A.; John D. Troup, M.I.MECH.E., M.I.CHEM.E.

*Paper:* Siam before the war. By Dr. Dudley Stamp

Twentieth Meeting, 23 March 1942. Geographical Sound films, by courtesy of the Belgian Government, with an introduction by the Comte de Briey. "Nos soldats d'Afrique"; "Musée du Congo Belge"; and "Sous l'étoile d'or"

Twenty-first Meeting, 30 March 1942. The President in the Chair

*Elections:* Ronald O. Benson, F.R.S.A., L.L.C.M.; Second-Lieut. Ronald Bromley, R.A.; Miss Mary G. Goss, B.A.; J. A. Lofthouse; Miss Eileen M. McGarry, B.A.

*Paper:* The early history of water-supply. By Mr. C. E. N. Bromehead